US Army Corps
of Engineers

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COMPUTER-AIDED STRUCTURAL
ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT ITL-90-6

USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL ANALYSIS OF U-FRAME OR W-FRAME STRUCTURES (CWFRAM)

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September 1990

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under Contract No. DACW39-88-C-0082

Monitored by Information Technology Laboratory
US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) Instruction Report ITL-90-6
6a. NAME OF PERFORMING ORGANIZATION See reverse. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION USAEWES Information Technology Laboratory
6c. ADDRESS (City, State, and ZIP Code)	7b. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. DACW39-88-C-0082
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame or W-Frame Structures (CWFRAM)

12. PERSONAL AUTHOR(S)
Jordan, Thomas D ; Dawkins, William P.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ________ TO ______	September 1990	260

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Computer-aided design; CWFRAM computer; Computer programs; Structural design

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The interactive computer program CWFRAM, described in this user's guide, performs an analysis of a two-dimensional slice of a U-frame or W-frame structure. The program functions in two modes, equilibrium and frame analysis.

In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and determines the necessary base-reaction distribution to equilibrate the external loads. In the frame analysis mode, a model of the structure is formulated and displacements and internal forces throughout the structure are determined from a linearly elastic analysis. OVER

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

90 11 13 068

6a. NAME OF PERFORMING ORGANIZATION (Continued).

Locks Subgroup, U-FRAME Structures Task Group
Computer-Aided Structural Engineering Project

19. ABSTRACT (Continued).

Information regarding the response of the structure is provided by this program with no actual design functions nor judgment offered as to the quality of the structural performance. Under certain conditions outlined herein, an analysis of a two-dimensional slice provides comparatively reliable indications concerning the behavior of the three-dimensional system.

Keywords: backfill soil, water, data input, computer aided design, structural loads, Army Corps of Engineers. (KR)

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PREFACE

This user's guide describes an interactive computer program, "CWFRAM," that analyzes a two-dimensional slice of a U-frame or W-frame structure. The program functions in two modes, equilibrium and frame analysis. The work in developing the program and writing the user's guide was accomplished with funds provided to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, by the Civil Works Directorate, Headquarters, US Army Corps of Engineers (HQUSACE), under the Computer-aided Structural Engineering (CASE) Project and by the US Army Engineer District, Louisville (CEORL), under the Olmsted Lock and Dam project.

Specifications for the program were provided by members of the Locks Subgroup, U-FRAME Structures Task Group of the CASE Project and the Structure Section, CEORL. Members of the Locks Subgroup during the period of development of the program were:

Mr. Byron Bircher, US Army Engineer District, Kansas City (Task Group Chairman)
Mr. Roger Hoell, US Army Engineer District, St. Louis (Subgroup Chairman)
Mr. Craig McRaney, US Army Engineer District, Vicksburg
Mr. Tom Quigley, US Army Engineer District, St. Louis
Mr. Tom Ruff, US Army Engineer District, St. Louis
Mr. William Steinbock, CEORL
Mr. Reed L. Mosher, WES

From CEORL, Ms. Anjana Chudgar and Mr. Bryon McCelland assisted in developing the program specifications.

The computer program and user's guide were written by Dr. William P. Dawkins, P.E., and Dr. Thomas Jordan, P.E., Stillwater, OK, under Contract No. DACW39-88-C-0082 with WES.

The work was managed, coordinated, and monitored in the Information Technology Laboratory (ITL), WES, by Mr. Mosher, Computer-Aided Engineering Division (CAED), under general supervision of Dr. Edward Middleton, Chief, CAED, Mr. Paul Senter, Assistant Chief, ITL, and Dr. N. Radhakrishnan, Chief, ITL. Mr. Donald Dressler was the HQUSACE point of contact for this work. This user's guide was published by ITL, WES.

COL Larry B. Fulton, EN, is the present Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
pounds (force)	4.448222	newtons
pounds (force) per foot	14.5939	newtons per metre
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	0.006894757	megapascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds per linear foot	14.5939	newtons per metre
square feet	0.09290304	square metres

USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL ANALYSIS OF U-FRAME OR W-FRAME STRUCTURES (CWFRAM)

PART I: INTRODUCTION

Description of Program

1. This user's guide describes a computer program "CWFRAM" for analysis of a two-dimensional (2-D) slice of a U-frame or W-frame structure. The program functions in two modes. In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and, for a soil-founded structure, determines the necessary base reaction distribution to equilibrate the external loads. In the frame analysis mode, a 2-D plane frame model of the structure (including piles if present) is formulated, and displacements and external forces throughout the structure (and pile forces) are determined from a linearly elastic analysis. This program provides information only regarding the response of the structure, performs no design functions, nor does it attempt to judge the quality of the structural performance.

Report Organization

2. This report is divided into the following parts:

   a. Part II: Describes the 2-D structure.

   b. Part III: Describes the external soil (backfill) and water system, the conversion of soil/water properties to structural loads, and other structural loads.

   c. Part IV: Describes the treatment of the base reaction for soil-founded structures and equilibrium analysis.

   d. Part V: Describes the 2-D model formulated for frame analysis including the effects of the piles for pile-founded structures.

   e. Part VI: Describes the computer program.

   f. Part VII: Presents example solutions obtained with the program.

Disclaimer

3. This program was developed using criteria furnished by the Computer-Aided Structural Engineering (CASE) task group on W-frame structures. The procedures and philosophy embodied in the program do not necessarily represent the views of the authors.

4. The program has been checked within reasonable limits to ensure that the results are accurate for the assumptions and limitations of the procedures employed. In all cases it is responsibility of the user to judge the validity of the results. The authors assume no responsibility for the designs or the performance of any structure based on the results of the program.

PART II: STRUCTURES

System Description

5. The U-frame or W-frame system is a three-dimensional (3-D) U-shaped or W-shaped structure, usually concrete, surrounded by soil backfill, founded on subsoil or piles, and subjected to a variety of soil and water (both internal and external) loads. Although an accurate assessment of the behavior of the system can be obtained only from a general 3-D analysis, such an analysis is clearly prohibitive, particularly during an iterative design process.

6. Under the following conditions, an analysis of a 2-D slice can provide relatively reliable indications of the behavior of the 3-D system:

- a. When the longitudinal dimension of the system is substantially larger than the width and height of the cross section.
- b. When the cross-sectional geometry of the structure, the soil and water conditions, support conditions, and other loading effects are relatively constant throughout an extended length of the system.
- c. When a 2-D slice of the system, obtained by passing parallel planes perpendicular to the longitudinal axis of the system, is representative of the adjacent slices and is sufficiently remote from any discontinuities in the geometry and loading (i.e., the slice is in a state of plane strain).

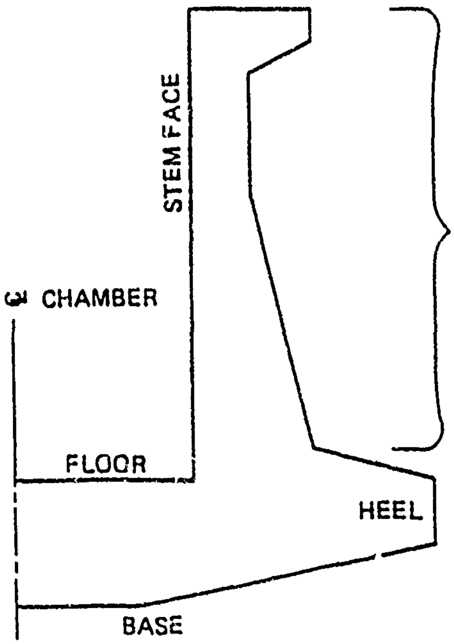
7. The remainder of this report is based on the assumption that the conditions presented in paragraph 6 exist in the 2-D representation.

Typical Cross Sections

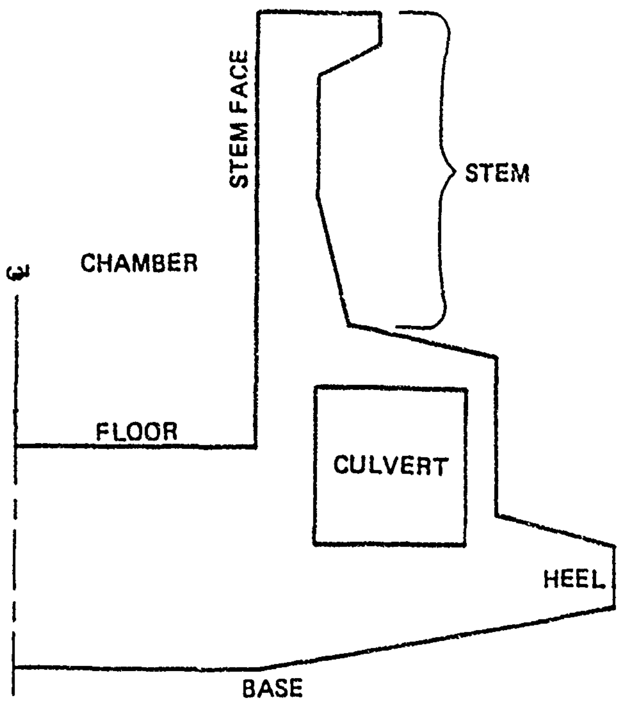
8. The geometry of a cross section (monolith) is usually dictated by its position in the 3-D structure. Although name identifiers are frequently assigned to the various shapes, the basic types (based on the configuration of the outside stems) shown in Figure 1 will be designated by a type number as follows:

- a. Type 1 monolith--no culvert or void.
- b. Type 2 monolith--with culvert, no void.
- c. Type 3 monolith--both culvert and void.

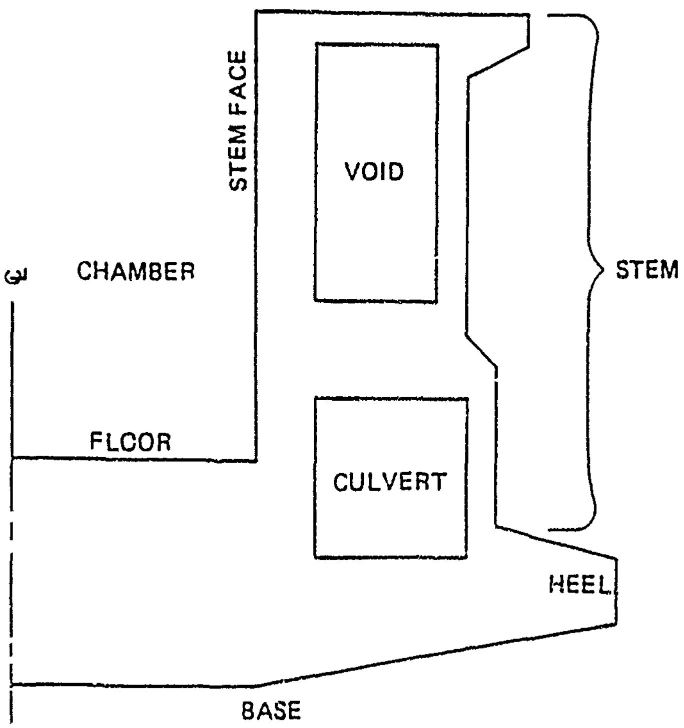
9. The center stem is not required, but when present the program provides the analysis for a W-frame structure. When present, its geometry shown



a. Type 1 monolith



b. Type 2 monolith



c. Type 3 monolith

Figure 1. Structural geometry, outside stems

in Figure 2 is always symmetric and will be designated by a monolith identifier as follows:

a. C1 monolith--no culvert or void.

b. C2 monolith--one culvert, no void.

c. C3 monolith--no culvert, closed void.

d. C4 monolith--no culvert, open void.

e. C5 monolith--one culvert, closed void.

f. C6 monolith--one culvert, open void.

g. C7 monolith--two culverts, no void.

h. C8 monolith--two culverts, closed void.

i. C9 monolith--two culverts, open void.

10. The typical sections shown in Figure 1 are shown for the rightside* outer stem of the structure. When the structure is symmetric about the centerline, only the right half stem data need be provided and a mirror image will be created for the leftside. In the unsymmetric system, the rightside and leftside must be described and the outside stems need not be the same type. In the equilibrium mode, there are few restrictions on the geometry of the outside stems (e.g., a stem may be described as having a "void" but without a "culvert"). In the frame analysis mode, the geometry is restricted to the three types illustrated in Figure 1; limitations for this mode are described further into this report.

11. In all cases, the structure is assumed to be monolithic, mass concrete. The effects of reinforcement, construction joints, expansion joints, or other discontinuities (cracking) in the system are not taken into account. In the frame analysis to be described later, the concrete is assumed to be linearly elastic and homogeneous.

Nomenclature, Assumptions, and Limitations

12. The various terms applied throughout this report and the assumptions and limitations employed (Appendix A: Guide for Data Input (additional definitions and limitations)) are listed:

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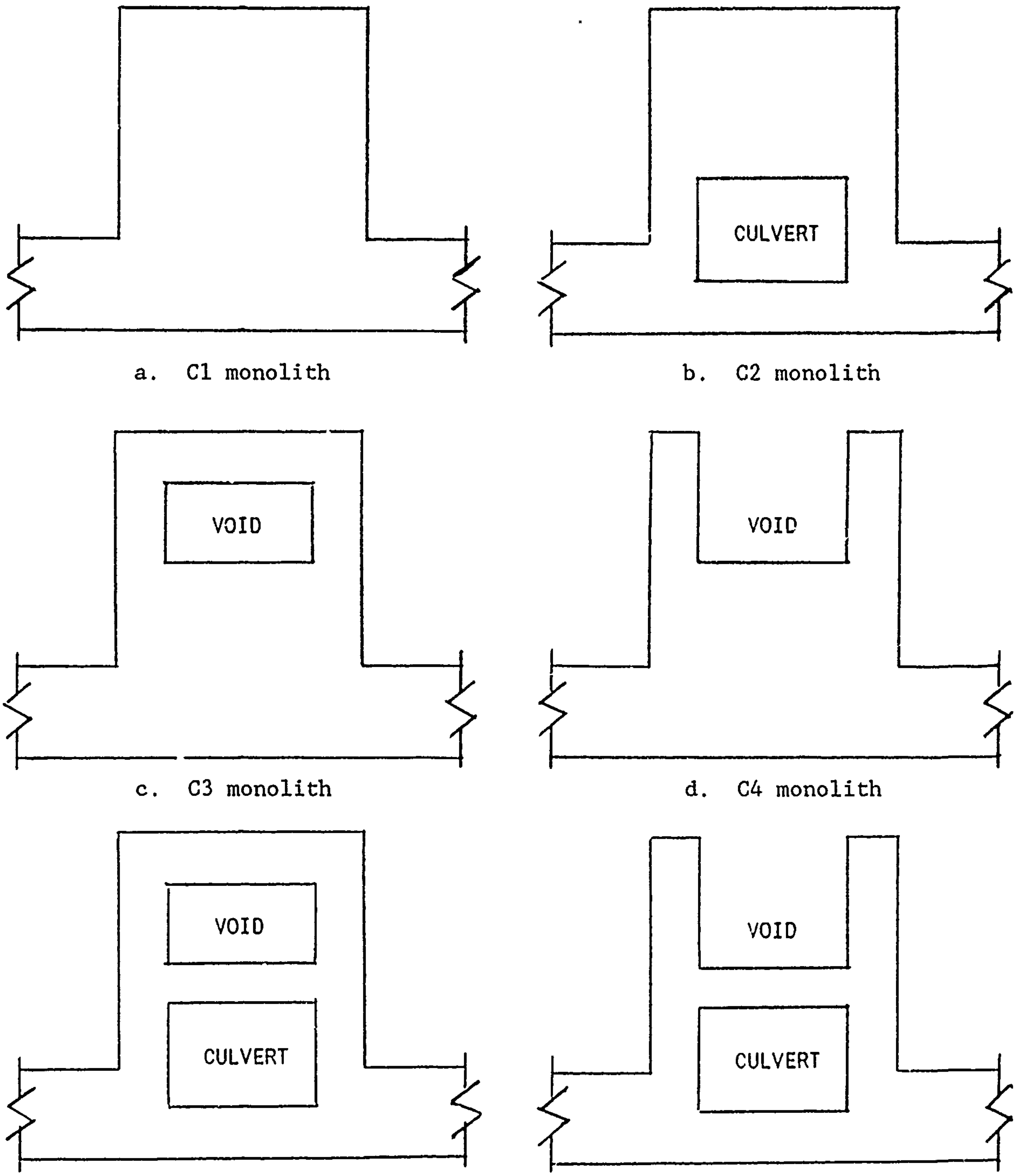
* The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the text to be consistent with these terms as used in the computer program CWFRAM.



a. C1 monolith

b. C2 monolith

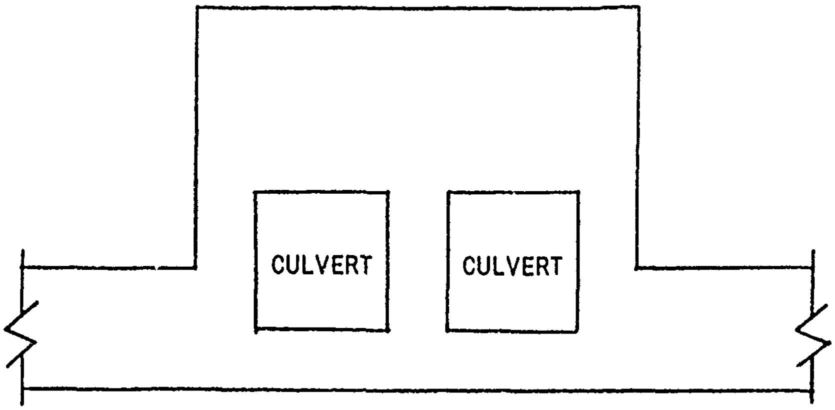
c. C3 monolith

d. C4 monolith

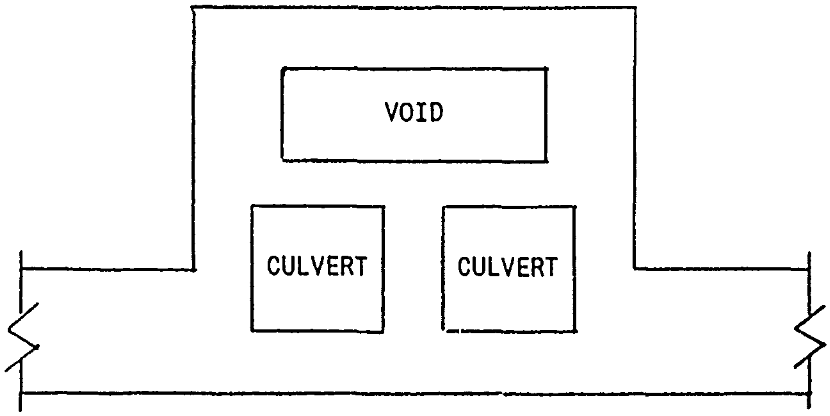
e. C5 monolith

f. C6 monolith

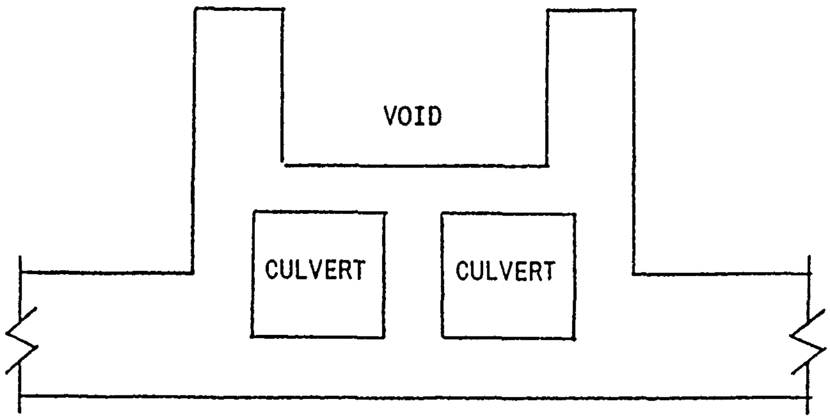
Figure 2. Structural geometry, center stem (Continued)



g. C7 monolith



h. C8 monolith



i. C9 monolith

Figure 2. (Concluded)

a. Centerline--vertical line midway between rightside and leftside interior stem faces or for the special case of a W-frame, vertical line of symmetry of the center stem.

b. Floor--bottom of the chambers, assumed to be horizontal.

c. Base--lower boundary of the structure, assumed to be horizontal to some distance from centerline, then sloping up or down.

d. Stem--the essentially vertical part of the structure above the floor.

e. Culvert--rectangular cavity in the vicinity of the intersection of a stem and base slab.

f. Void--rectangular cavity above the intersection of a stem and the base slab (above the culvert, when present).

g. Heel--protrusion of the base slab beyond an outside stem.

h. Elevation--vertical distance (feet), positive, measured upward from any selected datum.

i. Horizontal distance--positive dimension (right or left), measured from centerline unless otherwise noted.

j. Stem point--point on the outside face of an outside stem at which a change in geometry occurs; numbered sequentially downward with stem point 1 at the top of the stem.

k. Base point--point on the base at which a change in geometry occurs; limited to two on each side of the centerline; first point defines limit of horizontal segment of the base, which must extend past the face of the center stem; second point may be above or below first base point; for unsymmetric structures, the first base point on each side must be at the same elevation.

l. Stem face--inner vertical boundary of an outside stem or the vertical boundaries of the center stem.

PART III: BACKFILL SOIL AND WATER

Loading Effects

13. The fundamental loading effects on the structure are produced by soil acting on the external stem surfaces, water in the chambers, water in the culverts (and voids), water in the backfill, and by water and/or soil acting on the base. The user has the option to provide explicit magnitudes and distributions produced by these effects or to provide the physical characteristics of the soil and water that are converted to loadings by the computer program. The procedures used to convert physical properties to structure loading are described in the following paragraphs.

Backfill Soil

14. Backfill soil, if present, produces horizontal and vertical loads on the external stem surfaces. Backfill soil pressures may be described by an input pressure distribution or by the physical properties of the soil. The backfill soil profile may be composed of one to five horizontal soil layers. Soil layer 1 is the uppermost stratum with the other layers numbered sequentially downward. The last layer provided is assumed to extend ad infinitum downward. Each soil layer is characterized by these parameters:

a. Elevation (FT) at the top of the layer.

b. Saturated soil unit weight (γ_{SAT})* (PCF)--the saturated unit weight is used by the program to obtain the effective weight of submerged soil by subtracting the weight of the water from the saturated soil weight.

c. Moist soil unit weight (γ_{MST}) (PCF)--the weight of the unsubmerged soil.

d. Horizontal pressure coefficients at the top and bottom of the layer (KHT and KHB, respectively)--the coefficient is assumed to vary linearly from top to bottom of the layer, except in the last layer input where the coefficient is assumed to be constant at KHT.

e. Shear coefficients at the top and bottom (KVT and KVB, respectively) of the layer--the coefficient is assumed to vary linearly from top to bottom of the layer, except in the last layer input where the coefficient is assumed to be constant at KVT.

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* For convenience, symbols and abbreviations are listed in the notation (Appendix C).

(Note: The shear coefficient is intended to provide a means of approximating "down drag" effects produced by consolidation of the backfill that are not accounted for by ordinary gravity effects.)

15. A typical soil profile is shown in Figure 3a. When the ground-water elevation occurs within a soil layer, a temporary layer interface is automatically created at the ground-water elevation with soil properties evaluated as shown in Figure 3a. Horizontal and shear coefficients are obtained by linear interpolation between values at the top and bottom of the intact layer. Initially, soil properties are converted to effective vertical pressures at the top of each layer, Figure 3b. (Note: The surface surcharge, P_{vo} , may result from an applied surcharge on the ground surface or from surcharge water, or both.) Horizontal and shear soil pressures are obtained from the effective vertical soil pressures by applying the horizontal and shear soil coefficients at the top and bottom of the layer, Figures 3c and 3d. Horizontal shear soil pressures are assumed to vary linearly within a layer.

Soil Loading on Stems

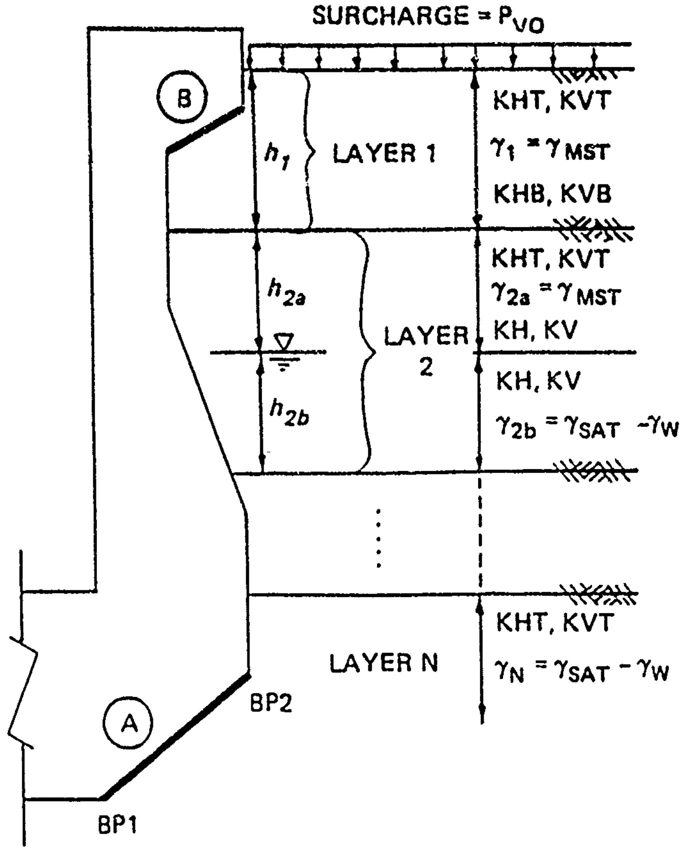
16. The resulting loading on the surface of the structure is obtained as illustrated in Figures 3e and 3f. The vertical, horizontal, and shear pressures acting on the vertical and horizontal surfaces of a soil element at the structure interface are converted, by Mohr's circle, to normal and tangential components on the surface of the structure.

Soil Force on Sloping Base

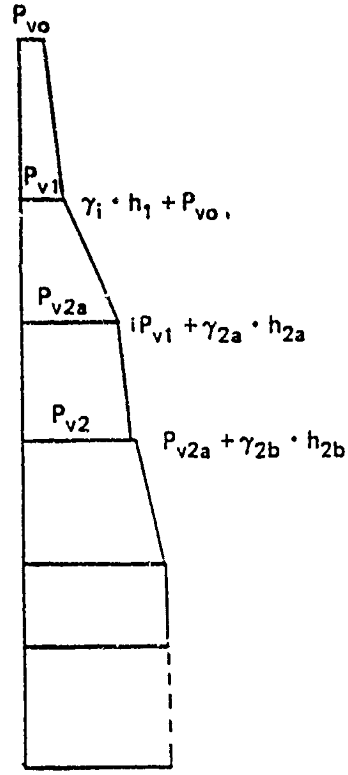
17. An upward sloping base (area A in Figure 3a) is subjected to the combined effects of backfill soil pressures and base soil reaction pressures, if present. In this case, only the horizontal component of the backfill soil pressure is applied to the slop zone.

Tension in the Backfill Soil

18. If backfill soil is in contact with the underside of an outward sloping segment of the stem surface (area B in Figure 3a), the combination of backfill soil pressures may result in a tension normal component. When this is encountered, the normal component is set to zero.

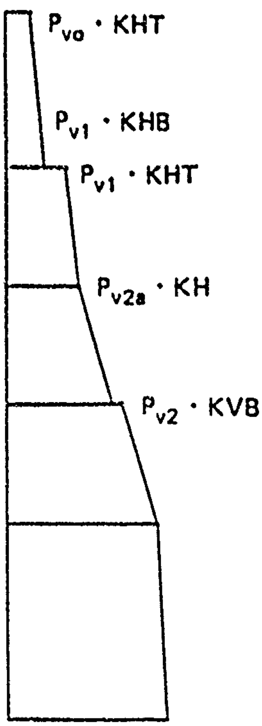


a. Backfill profile

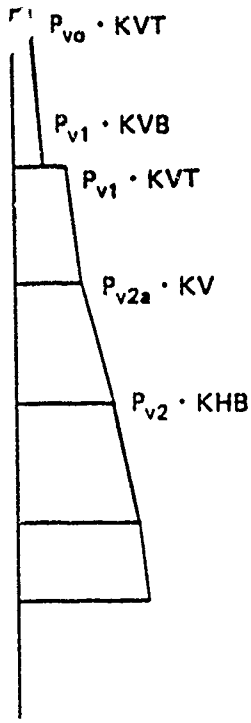


b. Vertical soil pressure

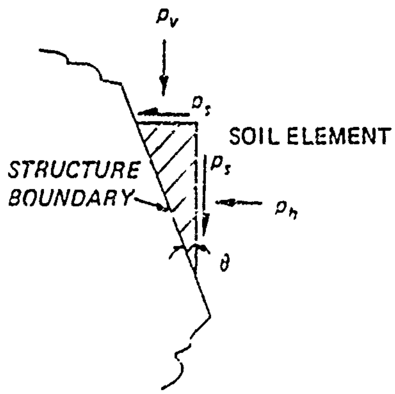
Figure 3. Backfill soil (Continued)



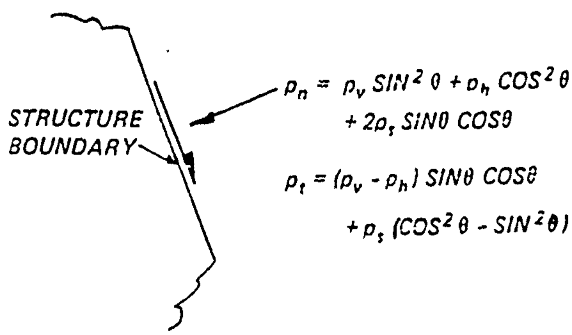
c. Horizontal soil pressure



d. Shear soil pressure



e. Soil/structural interface



f. Structural loading

Figure 3. (Concluded)

Water

19. Water loads may be applied to all surfaces of the structure, both internal and external. The user may select a variety of water loading effects as described in the following paragraphs.

Internal water

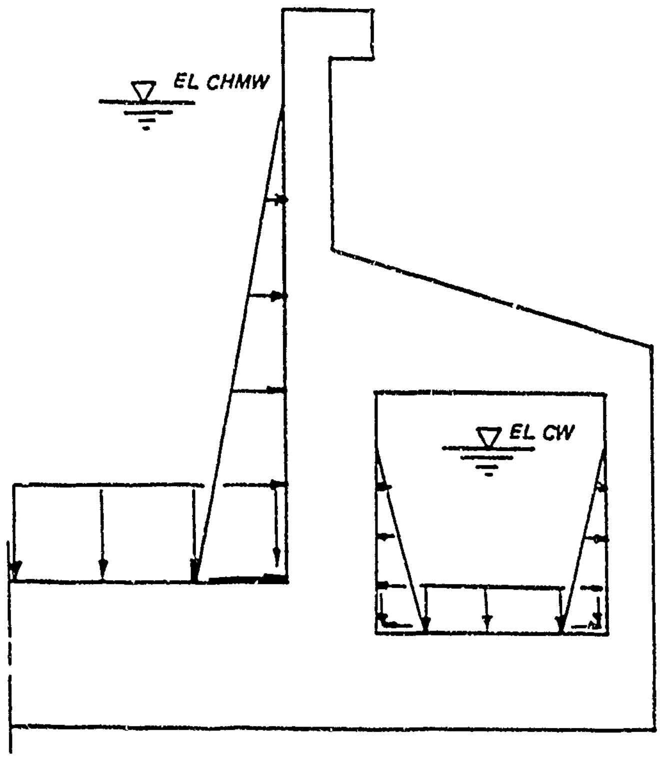
20. Internal water is defined to be any water producing loads on the chamber floors, the interior stem faces, the interior surfaces of culverts, and possibly on the interior surfaces of a void. Water effects are specified on the chamber floors and interior stem faces by an elevation of chamber water. The resulting load on the structure is a downward pressure on the chamber floors and a triangular horizontal pressure on the interior stem faces, Figure 4a.

21. The effective water elevation in the culverts is independent of the chamber water. When the elevation of water in the culvert is below the culvert roof, water loads are produced on the interior culvert surfaces as shown in Figure 4a. If the elevation of water in the culvert is specified above the culvert roof, water loads are produced on all surfaces of the culvert (Figure 4b).

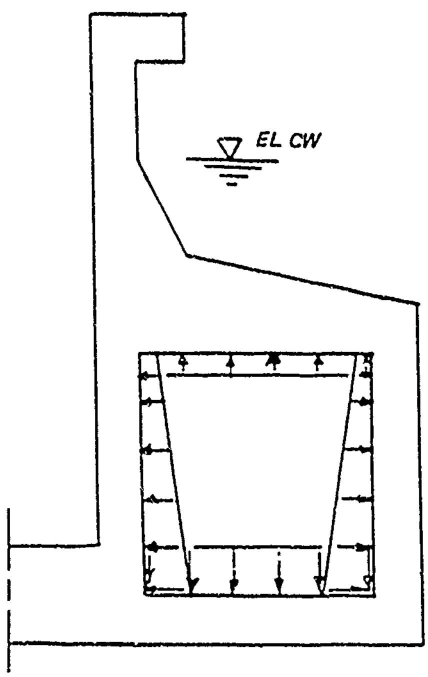
22. Culvert water may also produce loads on the interior walls of a void of an outside stem if the void floor and culvert roof are at the same elevation (Figure 4c). A center stem void, an outside stem void without a culvert, or an outside stem void with its floor above the culvert roof is assumed to be dry.

External water

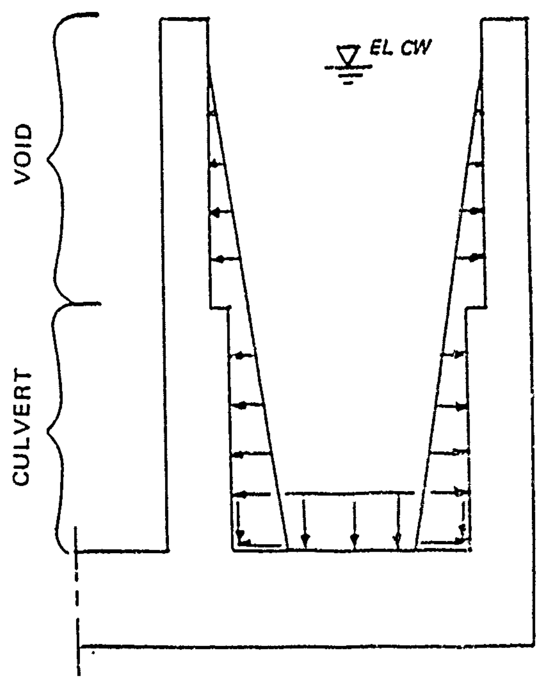
23. External water (water acting on the external stem surfaces) not only produces hydrostatic loads directly on the surface of the structure but may also affect backfill soil loads. The user may elect to provide external water effects in the form of a pressure distribution or by specifying the water elevations. An input pressure distribution is assumed to be the hydrostatic pressure, acting only on the surface of the structure with no effect on the backfill soil. Conversely, if a backfill soil pressure distribution has been provided, this distribution is not altered by the presence of external water.



a. Culvert water elevation below top of culvert



b. Culvert water elevation above top of culvert



c. Culvert and void connected

Figure 4. Internal water

Ground water

24. Ground water is defined to be that part of the external water that reduces the effective weight of the backfill soil in addition to producing hydrostatic pressures on the structure surface. The effective weight of any submerged soil is automatically determined by the program.

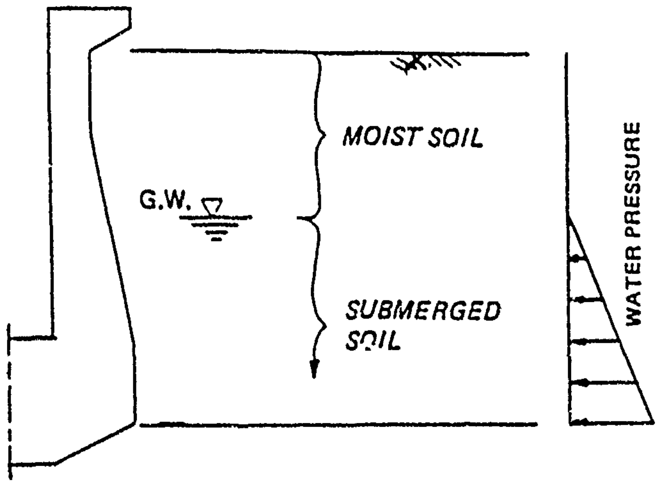
Surcharge water

25. An additional external water loading may be imposed in the form of surcharge water acting on the structure above the backfill soil surface. When surcharge water is present, the backfill soil surface is assumed to be covered by an impermeable membrane. Surcharge water produces hydrostatic pressures on the external surfaces of the structure above the soil surface. In additional to this, it produces a vertical surcharge load on the soil surface that increases soil effective pressures (hence, soil horizontal and shear pressures) below the soil surface. Various combinations of ground and surcharge water effects are shown in Figures 5a through 5c. Note that surcharge water does not affect submergence conditions in the backfill soil (Figure 5b). If both ground water and surcharge water are present and the ground-water elevation is above the soil surface, the resulting pressure distribution will be as shown in Figure 5c. Only surcharge water pressures are applied to the structure surfaces above the soil surface. Likewise, the surcharge load on the soil surface is the result of the surcharge water only. Below the soil surface, hydrostatic pressures on the structure surface and submergence effects are produced by ground water only. This combination will produce a discontinuity in the hydrostatic pressures at the soil surface.

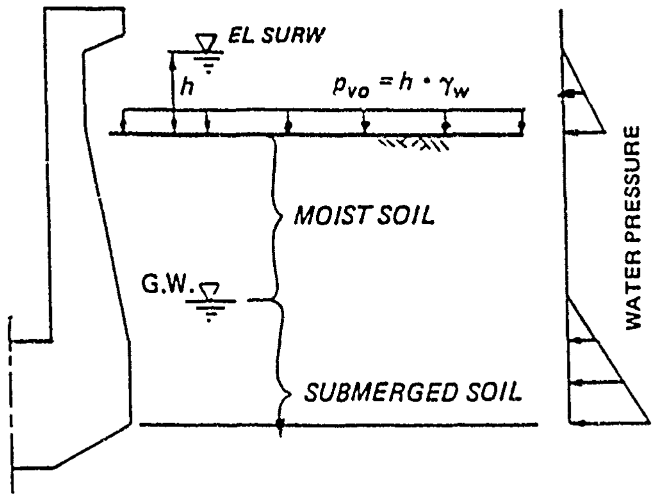
26. In the case of an upward sloping base as illustrated in Figure 2a, ground-water hydrostatic pressures on the structure are terminated at the elevation of base point 2. Any water effects below this elevation are assumed to be the result of uplift water.

Uplift water

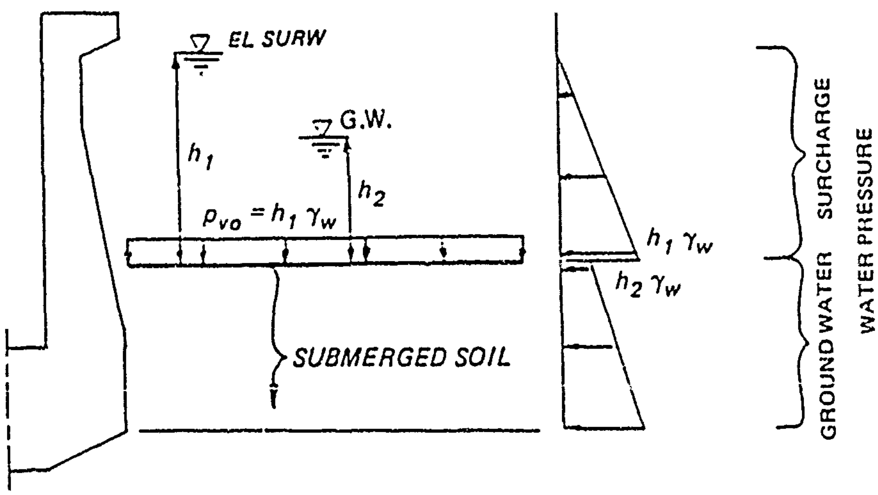
27. Uplift water effects on the base of the structure may be described by a pressure distribution or by specifying uplift water elevations on each side of the structure. When uplift water elevations are provided, it is assumed that the uplift head varies linearly across the structure between the right- and leftside elevations prescribed. Uplift water is assumed to be independent of ground water.



a. Ground water without surcharge water

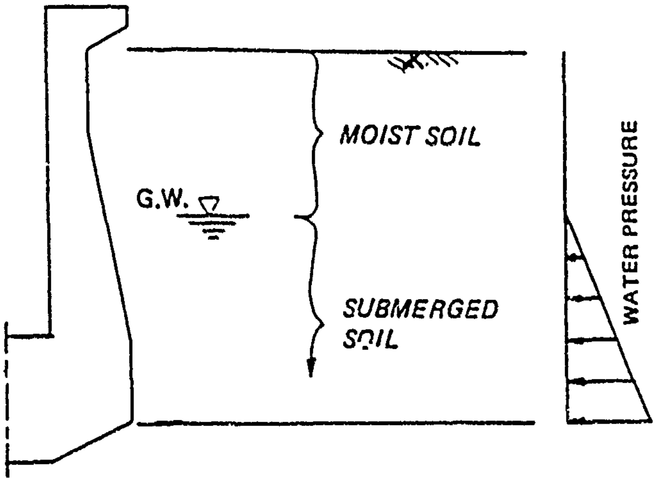


b. Surcharge water and ground water

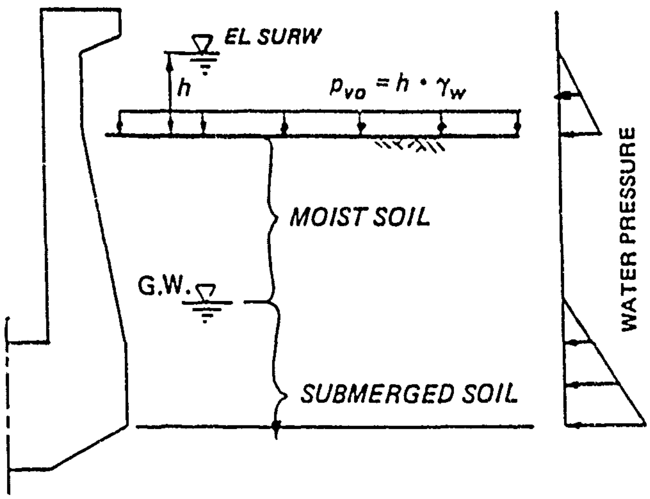


c. Ground water above soil surface

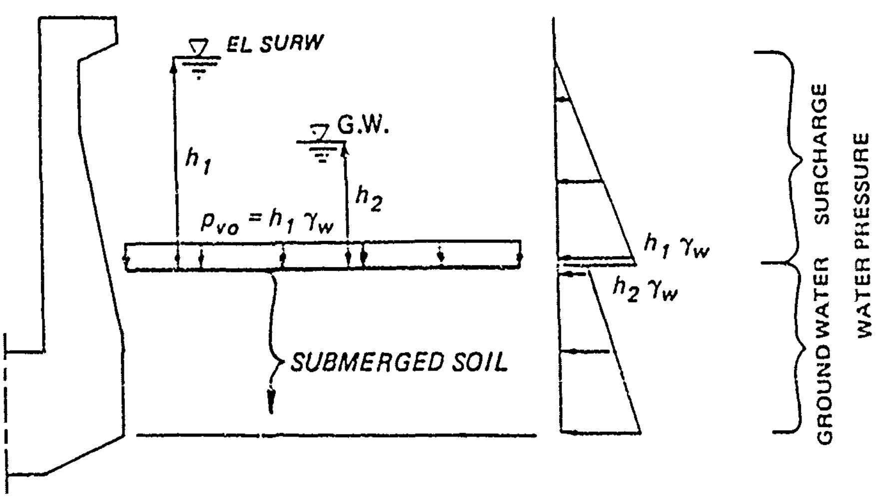
Figure 5. External water



a. Ground water without surcharge water



b. Surcharge water and ground water



c. Ground water above soil surface

Figure 5. External water

PART IV: BASE REACTION FOR SOIL-SUPPORTED SYSTEMS

30. In the case of a pile-supported structure, any unbalanced resultants (horizontal, vertical, or moment) will be equilibrated by forces developed in the piles. For soil-supported systems, unbalanced resultants are equilibrated by soil pressures acting on the base. A combination of soil and pile supports is not directly accommodated. However, an approximation of combined supports may be obtained by specifying a pile-supported structure and by applying additional loads to simulate soil support. Determination of base reaction pressures for soil-supported systems is described in the following paragraphs.

Symmetric Systems

31. In a symmetric system, only the vertical resultant of all loads will be nonzero. This resultant is equilibrated by vertical soil pressures acting on the horizontal projection of the entire base of the structure (i.e., from base point 2 on the leftside to base point 2 on the rightside). Equilibrium may be established automatically with one of the prescribed base pressure distributions described in paragraphs 33 through 35 or by a user-supplied distribution to be discussed subsequently.

Automatic base pressure calculations (symmetric system)

32. One of the three prescribed base pressure distributions may be selected from those shown in Figure 6. The procedures used to evaluate the pressures associated with each distribution are given in paragraphs 33 through 35.

Uniform distribution (symmetric system)

33. The base reaction pressure is uniform over the entire base:

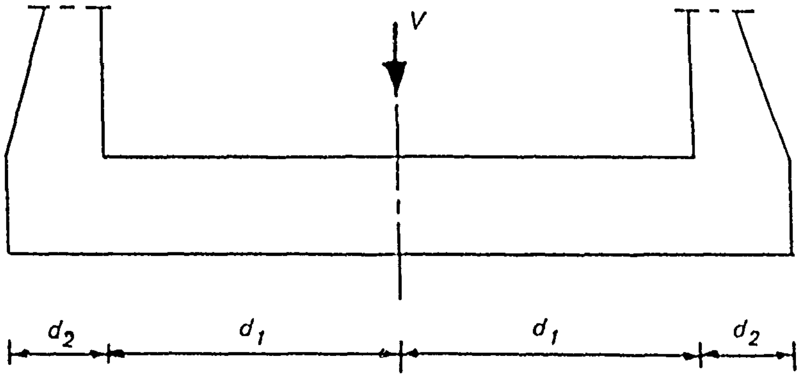
$$p_u = V/(2d_1 + 2d_2)$$

where

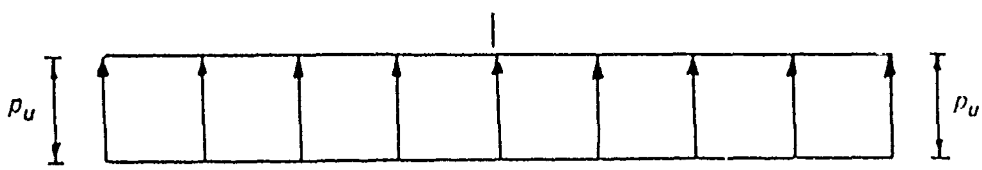
p_u = uniform pressure

V = net vertical reaction of the applied loads

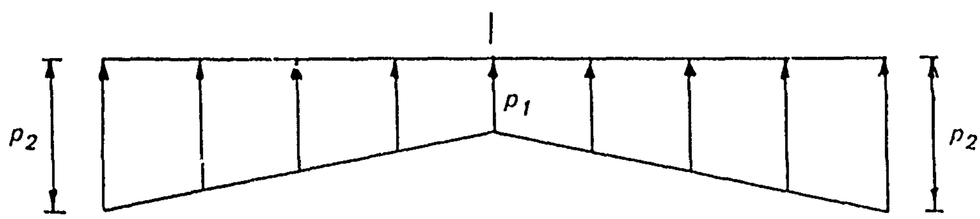
d_1, d_2 = dimensions shown in Figure 6a



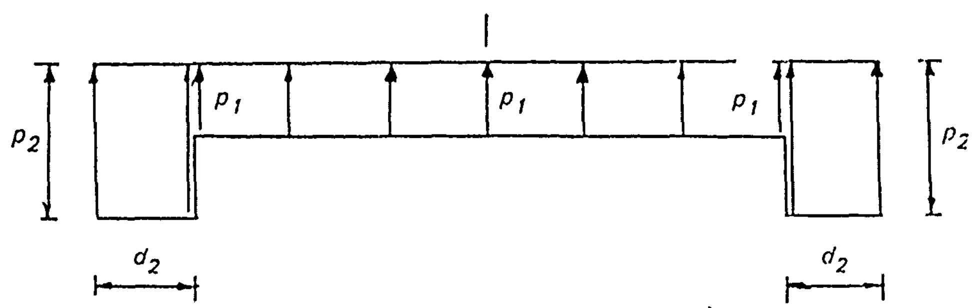
a. Symmetric system



b. Uniform



c. Trapezoidal



d. Rectangular

Figure 6. Automatic base reaction distributions for symmetric systems

Trapezoidal distribution
(symmetric system)

34. The base reaction pressure varies linearly from the centerline to the extreme edge of the base:

$$p_1 = R * p_u$$

$$p_2 = V/(d_1 + d_2) - p_1$$

where

p_1 = base pressure at the centerline

R = factor prescribed by the user ($0 < R < 2$)

p_u = uniform pressure from paragraph 33

p_2 = base pressure at extreme edge of the base

Rectangular distribution
(symmetric system)

35. The base pressure distribution is composed of three regions of constant pressure: p_1 under the region between the interior outside stem faces; p_2 under the regions from the interior outside stem faces to the extreme edges of the base:

$$p_1 = R * p_u$$

where

p_1 = uniform pressure between the interior outside stem faces

R = factor prescribed by the user [$0 < R < (d_1 + d_2)/2d_1$]

p_u = uniform pressure from paragraph 33

p_2 = uniform pressure from interior outside stem face to extreme edge of base = [$(V - 2p_1d_1)/2d_2$]

User-Specified Base Pressure Distribution

36. As an alternative to the automatically generated distributions just described, the user may prescribe any symmetric distribution desired. Because the net resultant of the vertical loads will usually not be known initially, the user-supplied distribution may not equilibrate the vertical resultant. The user may elect to have the program scale the input distribution to establish equilibrium, i.e.,

$$p_{actual} = p_{input} * (V/V_u)$$

where

p_{actual} = adjusted base pressure

p_{input} = user-specified pressure

V = net resultant of the applied vertical loads

V_u = vertical resultant of user-specified base pressure distribution

Unsymmetric System

37. In the unsymmetric system, any or all of the net resultants of applied loads may be nonzero. The procedures available to establish equilibrium of unsymmetric systems are described in the following paragraphs.

Unbalanced horizontal resultant

38. The unbalanced horizontal resultant on the 2-D slice would be equilibrated in the 3-D structure by friction along the base of the structure, by horizontal shear forces transmitted through the structure to adjacent slices, or a combination of the two. The user has several options for establishing horizontal equilibrium.

a. Base friction. Horizontal equilibrium is achieved by applying horizontal friction forces along the actual horizontal zone of the base (i.e., from base point 1 on the leftside to base point 1 on the rightside).

b. Base shear. Horizontal equilibrium is achieved by applying horizontal shear forces along the centerline of the base slab under the region between the interior outside stem faces.

c. Combination. A combination of base friction and base shear is not directly accommodated by the program. However, the user may use the additional load capability described previously to apply horizontal surface loads simulating shear or friction, or both, and direct any remaining horizontal unbalance to shear or friction, as described in paragraphs 38a and 38b.

Unbalanced vertical and moment resultant

39. Unbalanced vertical and moment resultants in unsymmetric systems are coupled and must be equilibrated simultaneously. Equilibrium of vertical and moment resultants is established as follows:

a. The net resultants of the applied loads, H, V, M_1 (M_1 = moment resultant about the centerline of the structure), are determined.

b. Horizontal equilibrium is satisfied as described in paragraph 38a.

c. A new moment resultant, M_2 , including the moment of base horizontal shear or friction, is determined for a point on the base at the centerline of the structure. (Note that for an unsymmetric structure, this point will not be the midpoint between the extreme edges of the base.)

40. An unsymmetric system and the final unbalanced vertical and moment, M_2 , resultants are shown in Figure 7a. The options available to the user to establish equilibrium depend on whether one of the automatic distributions for base pressure has been prescribed or whether the user has provided his own base pressure distribution.

Equilibrium with Automatic Base Pressure Distribution

41. When one of the three automated base pressure distributions has been selected, the following steps are used to establish vertical or moment equilibrium.

Vertical equilibrium

42. The vertical resultant is equilibrated by one of the initial distributions shown in Figures 7b, c, and d:

a. Uniform

$$p_u = V/1$$

b. Trapezoidal

$$p_1 = R * p_u$$
$$p_2 = 2V/1 - p_1$$

c. Rectangular

$$p_1 = R * p_u$$
$$p_2 = (V - p_1 c)/(d_2 + d_4)$$

Moment equilibrium

43. Because of the nonsymmetry of the above initial distributions, the net vertical resultant and the resultant of the initial distribution, while

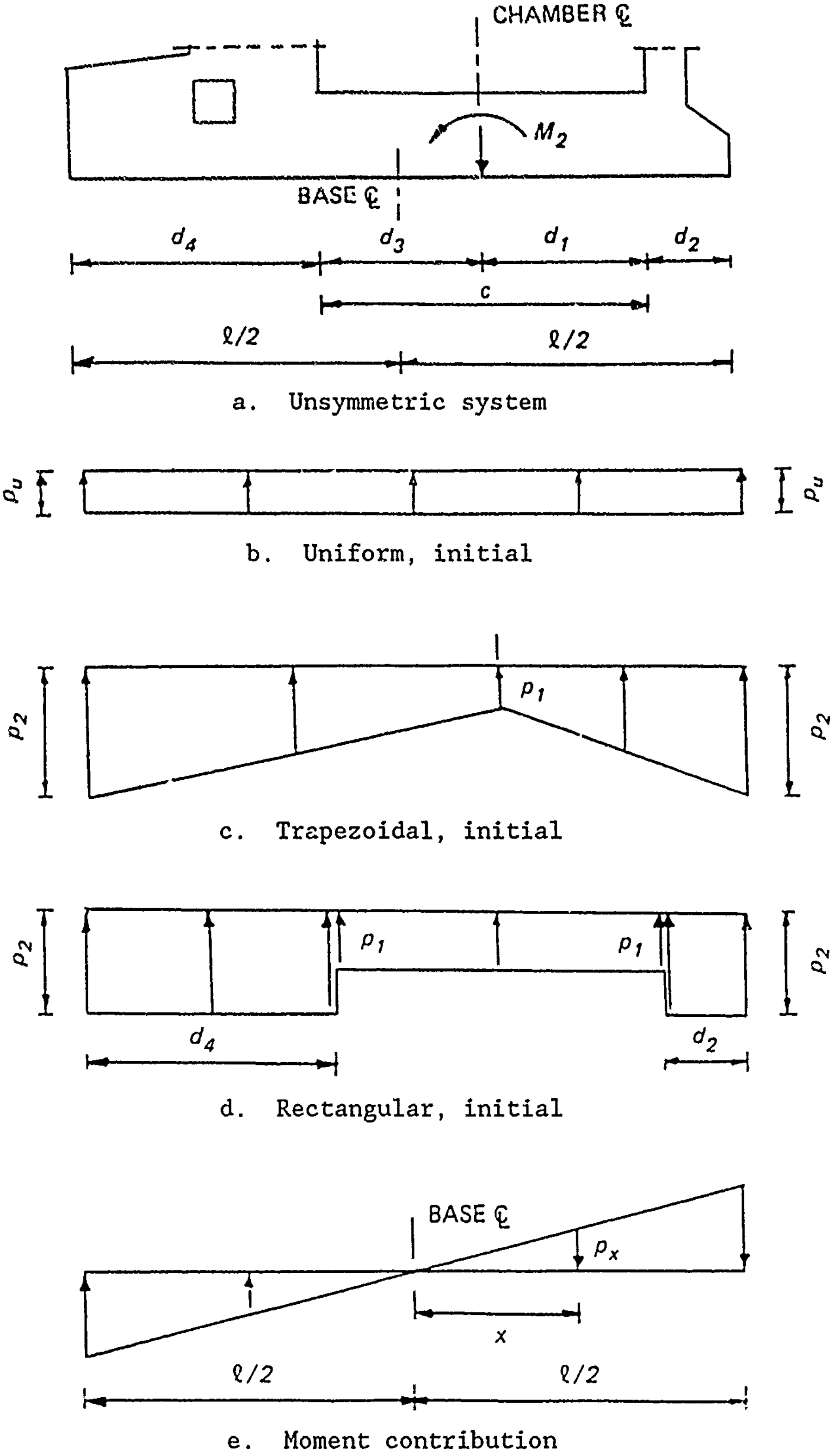


Figure 7. Automatic base pressure distributions for unsymmetric systems

equal in magnitude, will not be colinear. The couple formed by the two vertical resultants is added to the moment resultant, M_2, to form a third unbalanced moment resultant, M_3 (i.e., unbalanced moment about the base centerline). Equilibrium of this resultant is established by adding a linear pressure distribution to the initial base pressure distribution, Figure 7e:

$$p_x = -12\left(M_3 x/l^3\right)$$

where

p_x = pressure due to unbalanced moment

M_3 = unbalanced moment

x = distance from base centerline, positive to the right

l = width of the structure base

Equilibrium with user-supplied
base pressure distribution

44. Two options are available when the user-supplied base pressure distribution does not equilibrate the net vertical resultant, V, and the moment resultant, M_2.

Adjustment of the User-Supplied Distribution

45. Vertical equilibrium is established by augmenting the input pressure at each point according to

$$p_{actual} = p_{input} * V/V_u$$

where

p_{actual} = adjusted base pressure

p_{input} = user-specified pressure

V = net resultant of applied vertical loads

V_u = vertical resultant of user-specified base pressure distribution

46. Again, the couple due to the vertical resultant, V, and the resultant of the augmented pressure, V_u, is added to the net moment resultant, M_2, to form a final unbalanced moment resultant, M_3. This final resultant is equilibrated by adding a linear pressure distribution (paragraph 43) to the user-supplied distribution.

Vertical Structural Shear

47. Any portion of the vertical and/or moment resultant not equilibrated by the user-supplied base pressure distribution may be assumed to be resisted by vertical shear forces in the structure stems. The resultants of these structural shear forces are established according to

$$V_R = (V{*}d_L - M{*})/(d_L - d_R)$$
$$V_L = V{*} - V_R$$

where

V_R, V_L = resultants of vertical stem shear forces

$V*$, $M*$ = vertical and moment unbalances remaining after combining resultants of applied loads and resultants of user-supplied base reaction

d_L, d_R = distance from centerline to line of action of the leftside and rightside vertical shear forces. In the equilibrium mode, d_L (d_R) is the average thickness of the leftside (rightside) stem plus half of the distance between the interior outside stem faces. In the frame analysis mode, d_L , d_R are the distances from the centerline to the centroid of the inside rigid block of the outside stems (paragraph 63).

Negative Base Pressures

48. In the severely unsymmetric system, combination of the linear pressure distribution due to moment unbalance with the initial automatic or user-supplied base pressure distribution may result in negative (i.e., tension) base pressures. When this condition is encountered, the user is notified by the program and execution is terminated.

Equilibrium Mode

49. Evaluation of soil, water, and base reaction pressures and net unbalanced resultants (for pile-supported structures) constitutes the extent of the computations performed in the equilibrium mode. The user should exercise the program in this mode to verify structural loadings and resultants before attempting a complete frame analysis. It should be noted that an

equilibrium analysis may be performed for a variety of structures not accommodated in the frame analysis mode.

PART V: FRAME ANALYSIS

General Overview

50. The equilibrium phase of the analysis described in paragraph 49 determines the distribution of loads around the periphery of the structure. When a frame analysis is specified, relative displacements and axial, shear, and bending moment forces are evaluated throughout the structure using a 2-D plane frame model of the structure.

Restrictions on Structural Geometry

51. There are few limitations on the structural geometry when the program is exercised in the equilibrium mode. To perform a frame analysis, the following limitations are imposed. (In the following discussion, the term "monolith" refers to the shape of the outside stems of the structure. A structure may have different types of monoliths on each side. However, the elevation of the floor and the elevation of the first base point must be the same on both sides of centerline.)

52. There are six basic monoliths permitted for frame analysis: type 1, type 2, and four variations of type 3, subsequently designated as types 31 through 34. The requirements on geometry for each of the monoliths and the center stem are discussed below. In the following descriptions, reference is made to "rigid blocks" at various locations in the structure. This term and the effects of rigid blocks will be discussed later in this report.

Type 1 Monolith

53. A type 1 monolith, Figure 8, has neither a culvert nor a void in the outside stem. Six stem points, S1 through S6, are required with the following limitations on horizontal distance from the stem face (D_i) and elevation (E_i) for the i^{th} stem point:

- a. $E_1 > E_f$, $D_1 > 0$
- b. $E_2 < E_1$, $D_2 = D_1$
- c. $E_3 \leq E_2$, $D_3 \leq D_2$

(Stem points S1 through S3 define the top rigid block B6.)

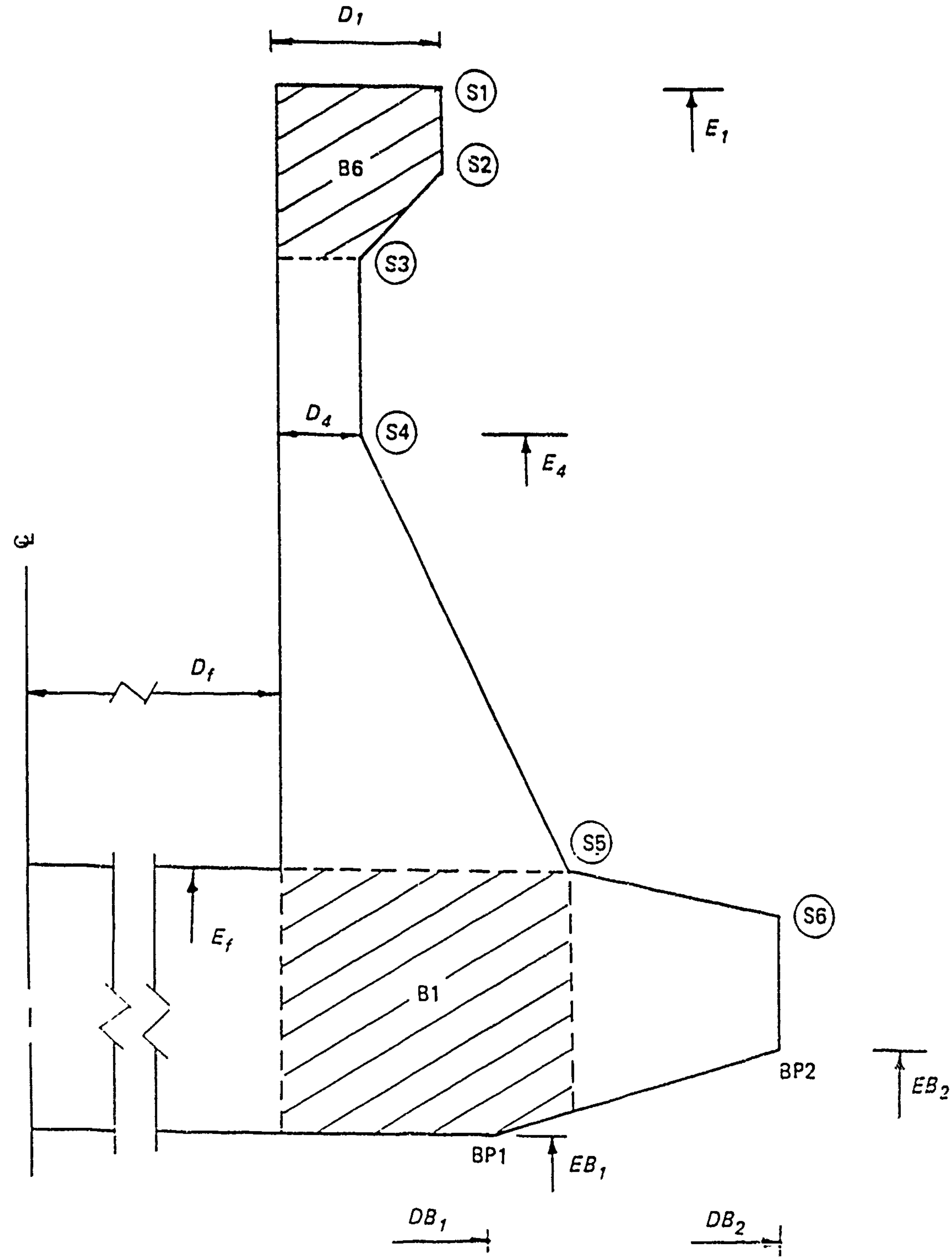


Figure 8. Type 1 monolith

d. $E_3 > E_4 > E_5$, $D_4 > 0$

e. $E_5 \leq E_f$, $D_5 > 0$

(Stem point S5 defines one limit of rigid block B1.)

f. $E_6 \leq E_5$, $D_6 \geq D_5$

(If $E_6 = E_5$ and $D_6 = D_5$, heel is omitted)

g. If only one base point provided,

$E_{B1} < E_6$, $D_{B1} = D_f + D_6$

h. If two base points provided,

$E_{B2} < E_6$, $D_{B2} = D_f + D_6$

$D_{B1} \leq D_f + D_5$

Type 2 Monolith--Standard Case

54. A type 2 monolith, Figure 7, has a culvert in the stem but no void. Eight stem points are required and five (B1, B2, B3, B4, B6) rigid blocks are associated with the standard case. The following limitations are imposed:

a. The bottom of the culvert must be at or the elevation of the chamber floor

b. The top of the culvert must be above the elevation of the chamber floor.

c. $E_1 > E_f$, $D_1 > 0$

d. $E_2 < E_1$, $D_2 = D_1$

e. $E_3 \leq E_2$, $D_3 \leq D_2$

f. $E_3 > E_4 > E_5$, $D_4 > 0$

(Stem points S1, S2, S3 define block B6.)

g. E_5 above top of culvert, $D_5 > 0$

(S5 defines one limit of block B3.)

h. $E_6 \leq E_5$, $D_6 \geq D_5$, stem point S6 must be above and outside of top, outside corner of culvert

i. $E_7 < E_6$, $D_7 > 0$

(S7 defines one limit of block B1.)

j. $E_8 \leq E_7$, $D_8 \geq D_7$

(If $E_8 = E_7$ and $D_8 = D_7$, heel is omitted.)

k. If one base point provided,

$E_{B1} < E_8$, $D_{B1} = D_f + D_8$

l. If two base points provided,

$E_{B2} < E_8$, $D_{B2} = D_f + D_8$

$D_{B1} \leq D_f = D_7$

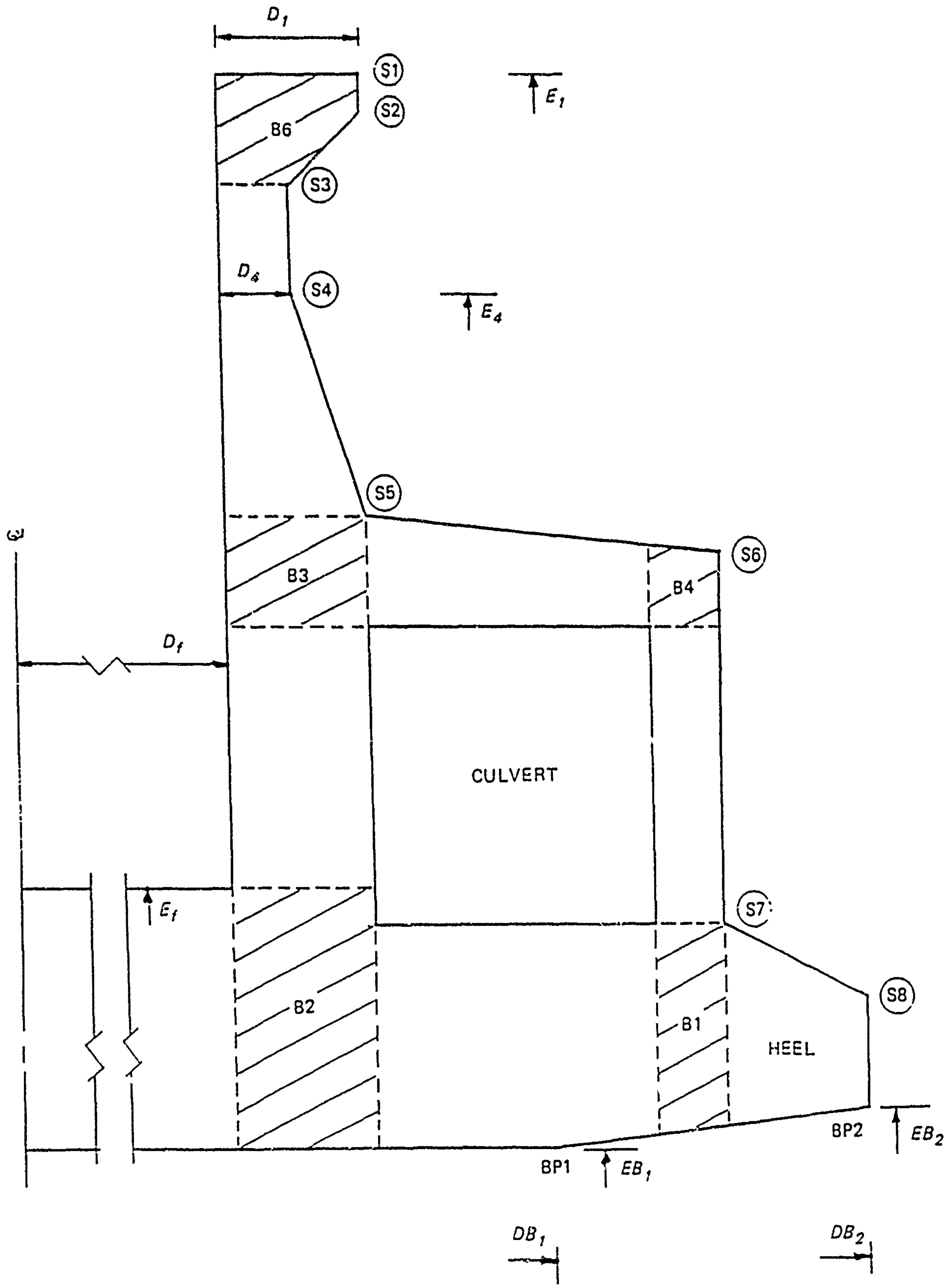


Figure 9. Type 2 monolith, standard case

55. In some special cases of the type 2 monolith, it may be desired that the entire culvert roof be treated as a rigid block, i.e., blocks B3 and B4 merge into a single rigid block. To impose this case, Figure 10, stem points S5 and S6 must coincide (E5 = E6 , D5 = D6). All other restrictions of the standard type 2 monolith apply.

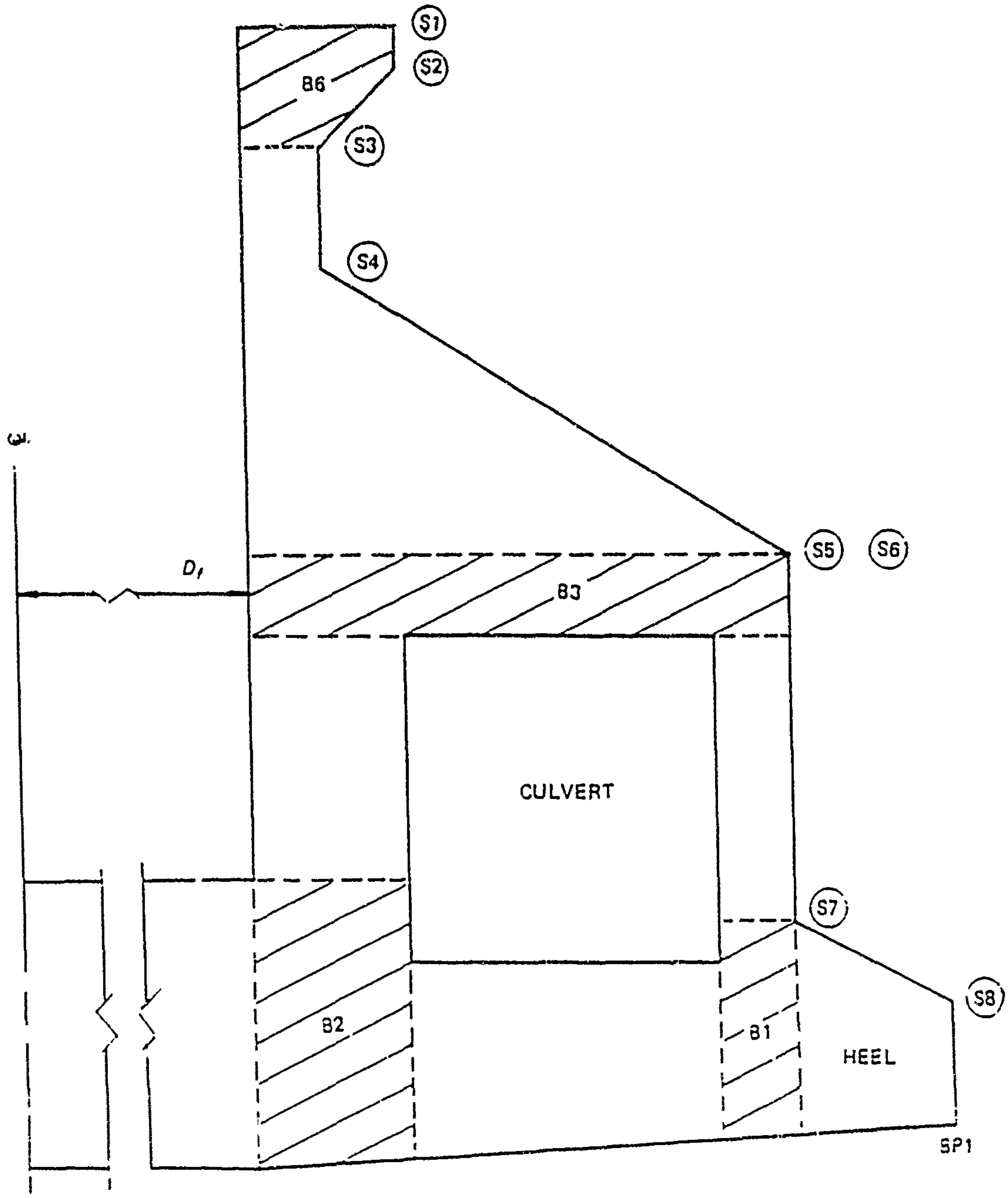


Figure 10. Type 2 monolith, special case

Type 3 Monolith--Variations

56. A type 3 monolith must have both a culvert and a void in the outside stem with six associated rigid blocks. Depending on the dimensions of the culvert and void, four distinct variations (types 31, 32, 33, and 34) of a type 3 monolith may arise. In all cases, the floor of the culvert must be at or below the elevation of the chamber floor and the top of the culvert must be above the chamber floor.

Type 31 monolith

57. The culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is closed ($E_1 > E_v + H_v$). Seven stem points are required, as shown in Figure 11.

a. $E_1 > E_f$, $E_1 > E_v + H_v$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 > D_3 > D_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_4 < E_3$, $D_4 > D_v$

e. $E_4 \geq E_5 \geq E_c + H_c$, $D_5 > D_c$

f. $E_5 > E_6 < E_c + H_c$, $D_6 > D_c$

(Stem point S6 defines block B1.)

g. $E_7 \leq E_6$, $D_7 > D_6$

(If S6 and S7 coincide, heel is omitted.)

h. If only one base point provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$

$D_{B1} \leq D_f + D_7$

Type 32 monolith

58. The culvert and void are connected (i.e., $E_v = E_c + H_c$), and the top of the void is closed (i.e., $E_1 > E_v = H_v$). A type 32 monolith has four rigid blocks (B1, B2, B5, B6). A discussion of the effect of discontinuities in the culvert and void walls at their intersections will be discussed (i.e., blocks B3 and B4 of the type 31 monolith degenerate to lines). Five stem points are required, as shown in Figure 12.

a. $E_1 > E_v + H_v$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

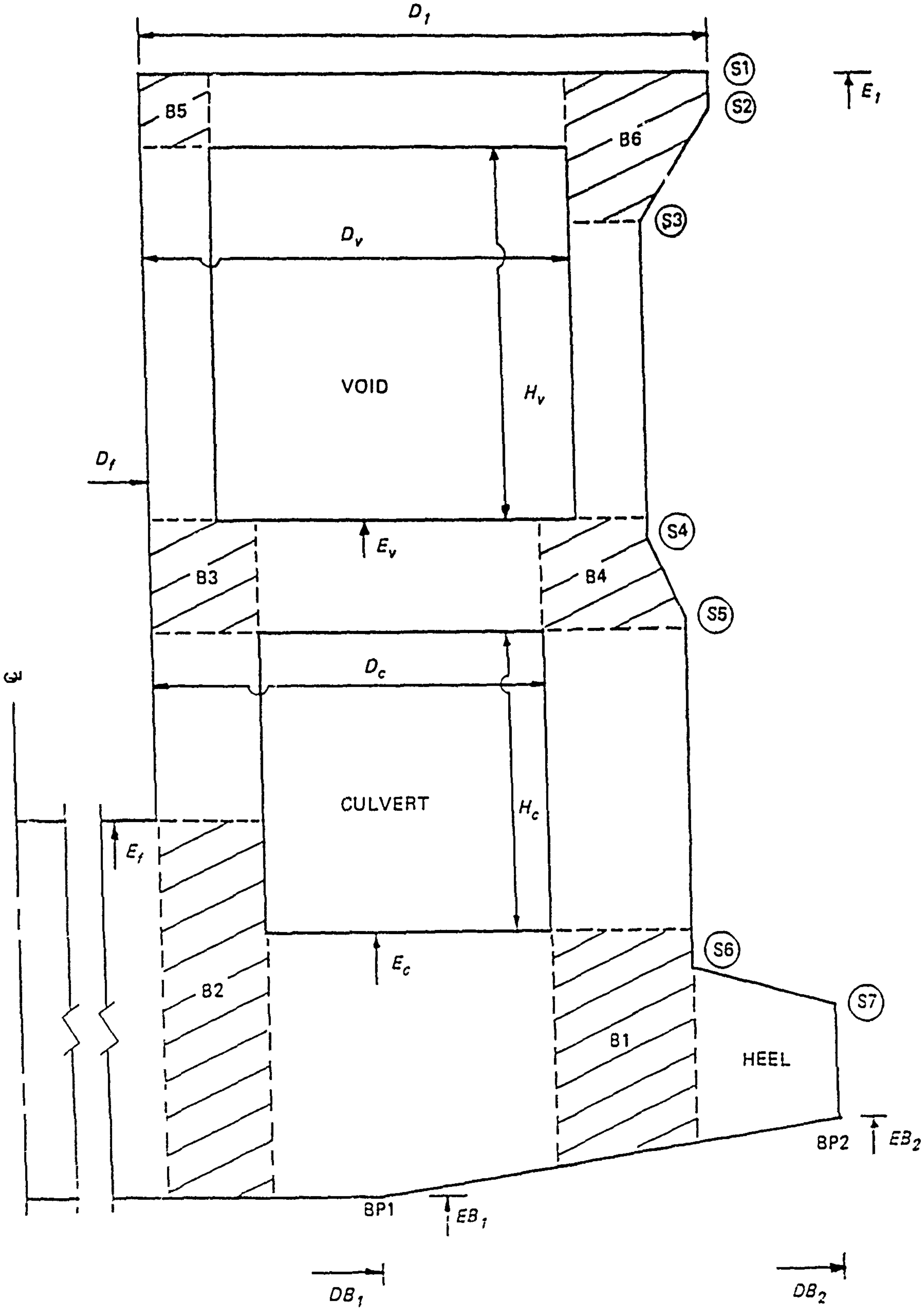


Figure 11. Type 31 monolith

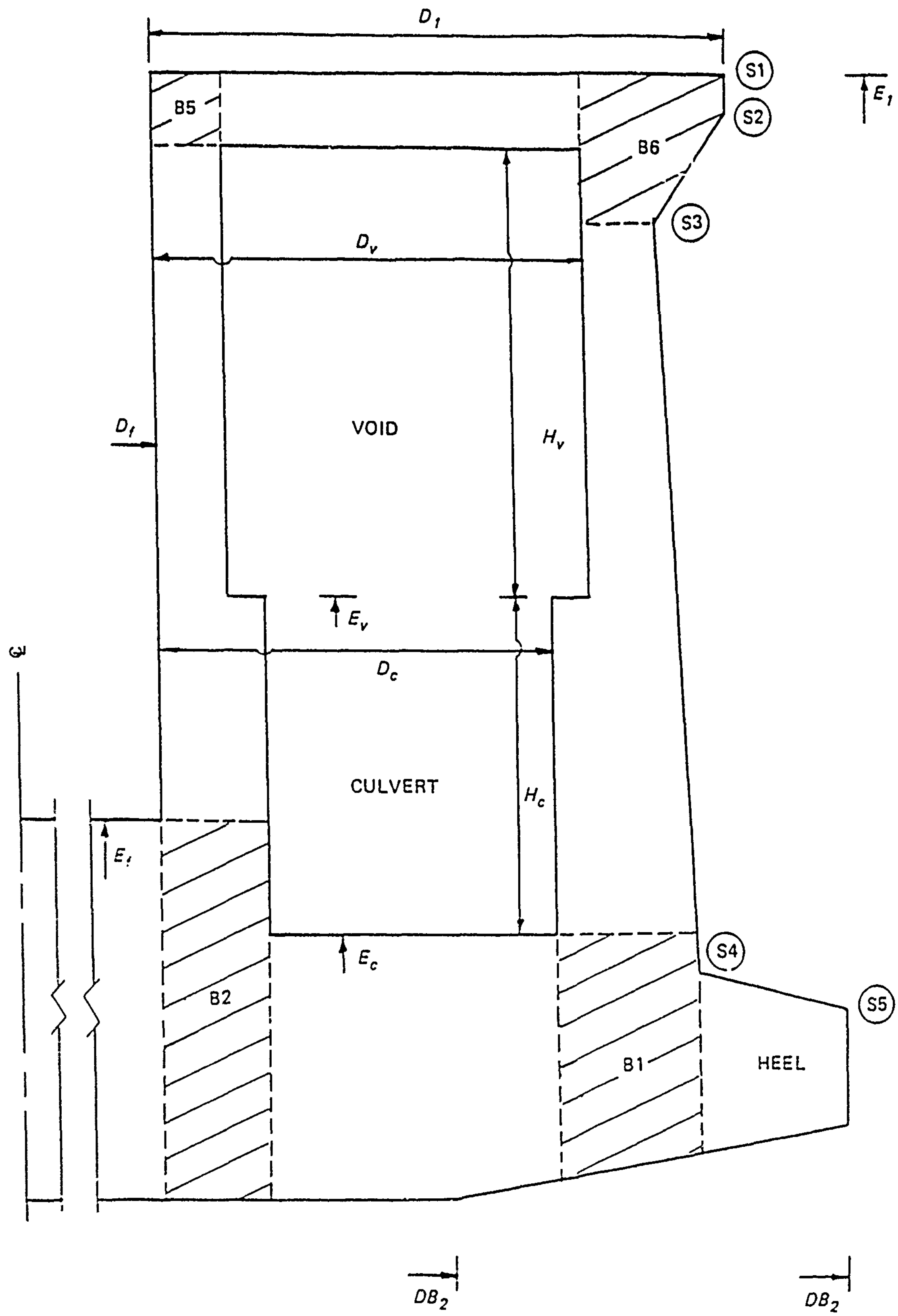


Figure 12. Type 32 monolith

c. $E_3 \le E_2$, $D_2 \ge D_3 > D_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_4 < E_v$, $D_4 > D_c$

e. $E_5 \le E_4$, $D_5 \ge D_4$

(If S4 and S5 coincide, heel is omitted)

f. If only one base point provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$

$D_{B1} \le D_f + D_4$

Type 33 monolith

59. The culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is open (i.e., $E_1 + E_v + H_v$). A type 33 monolith has five rigid blocks (B1, B2, B3, B4, B6). Block B5 of the type 31 monolith is absent. Seven stem points are required, as seen in Figure 13.

a. $E_1 = E_v + H_v$, $E_1 > E_f$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_v < E_3 \le E_4$, $D_v < D_3 \le D_2$

(Stem points S1, S2, S3 define block B6.)

d. $E_c + H_c < E_4 < E_v$, $D_4 > D_v$

e. $E_4 \ge E_5 \ge E_c + H_c$, $D_5 > D_c$

(Stem point S6 defines block B1)

f. $E_6 < E_5$, $D_6 > D_c$

g. $E_7 \le E_6$, $D_7 \ge D_6$

(If S6 and S7 coincide, heel is omitted)

h. If only one base point provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$

$D_{B1} \le D_f + D_6$

Type 34 monolith

60. The culvert and void are connected (i.e., $E_v = E_c + H_c$) and the void top is open (i.e., $E_1 = E_v + H_v$). A type 34 monolith has three rigid blocks (B1, B2, B6). Blocks B3 and B4 degenerate to lines; block B5 is absent. Figure 14 shows the five stem points that are required.

a. $E_1 = E_v + H_v$, $E_1 > E_f$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

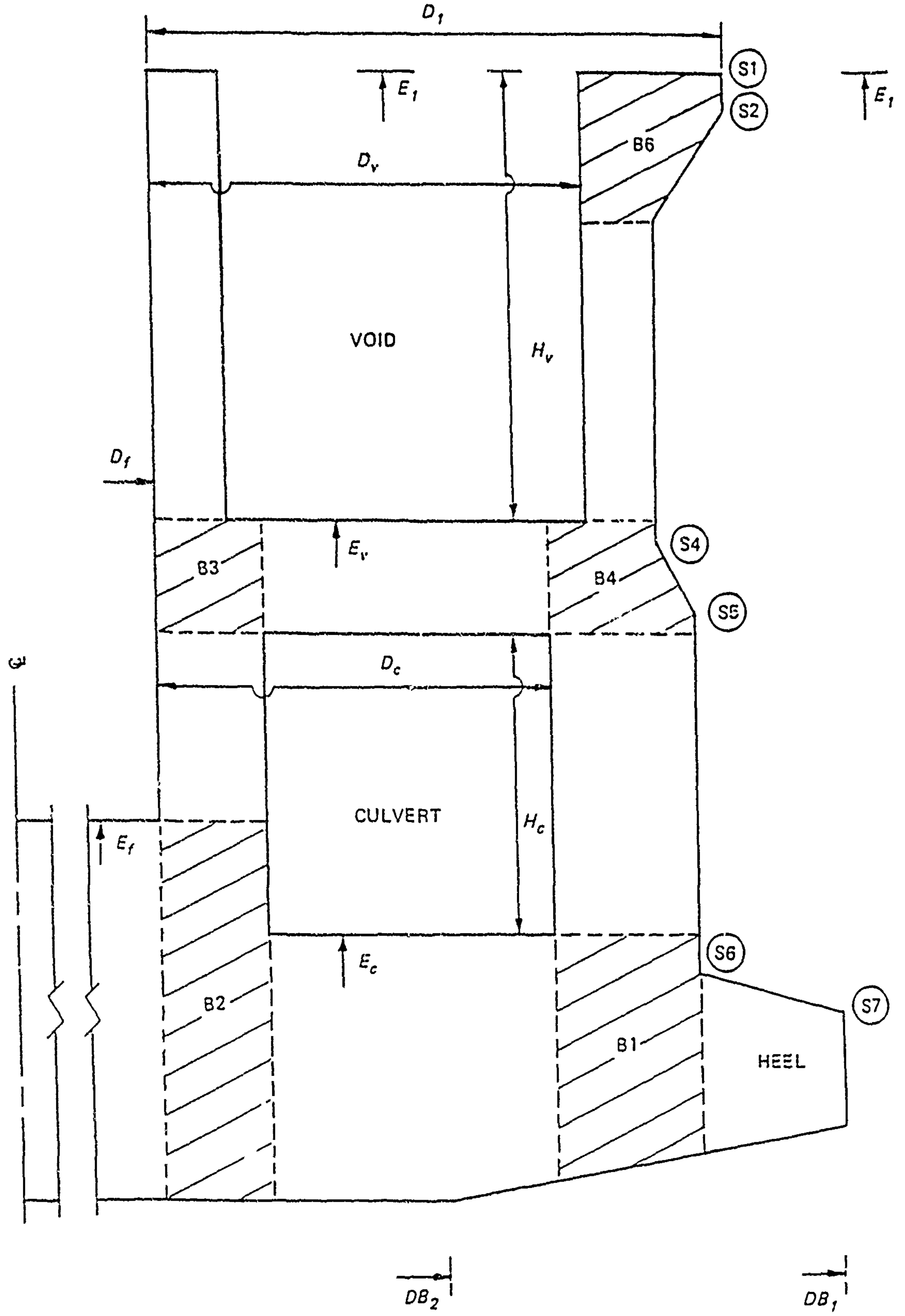


Figure 13. Type 33 monolith

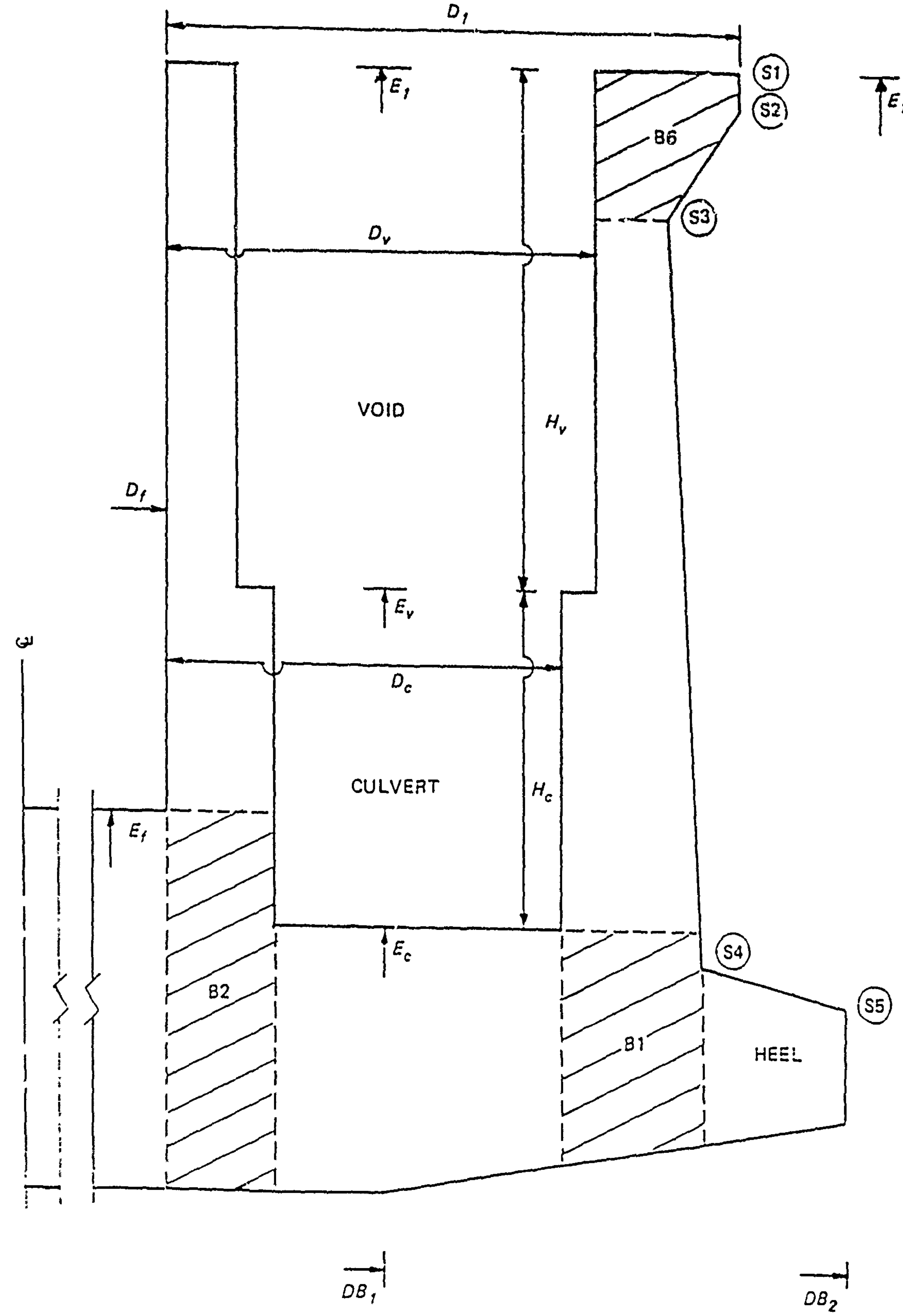


Figure 14. Type 34 monolith

c. $E_v < E_3 \leq E_2$, $D_v < D_3 \leq D_2$

(Stem points S1, S2, S3 define block B6)

d. $E_4 < E_c + H_c$, $D_4 > D_c$

(Stem point S4 defines block B1.)

e. $E_5 \leq E_4$, $D_5 \geq D_4$

(If S4 and S5 coincide, heel is omitted.)

f. If only one base point provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$

$D_{B1} \leq D_f + D_4$

Center Stem

61. A center stem may be combined with any combination of 'type' monoliths described to form a W-frame structure. Depending on the existence of a void and the number of culverts, nine distinct variations of center stem geometry (C1 through C9 monoliths) may arise. Additional restrictions to the dimensions of the structure apply for the analysis of a W-frame.

a. The center stem including culvert(s) and void is symmetric about the centerline.

b. Base point one is larger than one-half of the center stem width.

c. The floor width is the same on both sides of centerline and larger than one-half of the center stem width.

d. The floor elevation is the same on both sides of centerline.

Caution

62. Myriad checks of user input and edited data are performed by the computer program to ensure compliance of the data with the assumptions and restrictions described. Because the variations of structural geometry and loading are innumerable, it is possible that some descriptions are accepted by the program for which strict compliance has not been met. It is the responsibility of the user to verify that any results produced by the program are appropriate for his system.

Frame Model

63. Structural analysis of the U-frame or W-frame is based on the assumption that the various slabs, walls, etc. of the structure interact as elements (members) of a 2-D plane frame. Establishment of a plane frame representation of the structure requires designation of parts of the structure as flexible "members" connected at their ends to joints. While some regions of the structure may lend themselves to treatment as flexible members (i.e., beam bending elements), there exist significant zones of mass concrete that cannot be assigned bending characteristics. These zones, alluded to previously, have been assumed to be rigid. The location and extent of these rigid blocks, the effect on the members connected to the blocks, the member characteristics, and locations of joints are described in the following paragraphs.

Rigid Blocks (Types 1, 2, and 3 Monoliths)

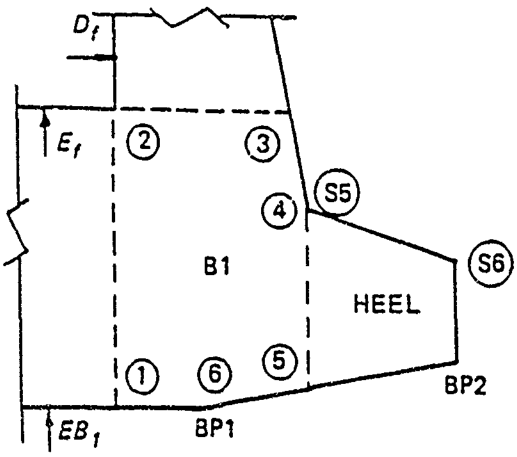
64. Depending on the type of monolith, from two to six blocks are defined. The size and shape of the rigid blocks are determined by the relative positions of the various input dimensions of the outside stems. The geometry of each rigid block is prescribed by elevations and distances from the centerline at six points around the periphery of each block as is presented in paragraphs 65 through 73.

Block B1 (type 1 monolith)

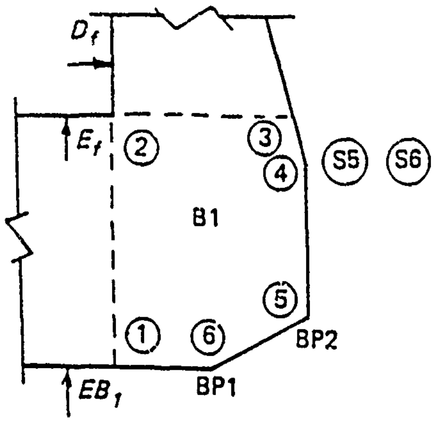
65. In a type 1 monolith, block B1 is at the intersection of the base slab and stem (and heel, if present). The locations of the six points on the block for several example combinations of structural dimensions are shown in Figure 15 by the circled numbers. Any corner of the block not coinciding with the location of a stem or base point is obtained by linear interpolation between the two bounding input points.

Block B1 (type 2 and type 3 monoliths)

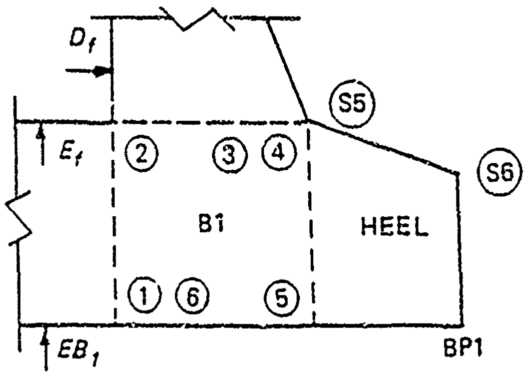
66. Block B1 in a type 2 monolith or any of the type 3 monoliths occupies the intersection of the base slab and the outside culvert wall (and heel, if present). Examples of block B1 geometries for a type 2 monolith are shown in Figure 16. Identical geometries apply to any of the type 3 monoliths, except that the last two stem points are: S6 and S7 for types 31 and 33; and S4 and S5 for types 32 and 34.



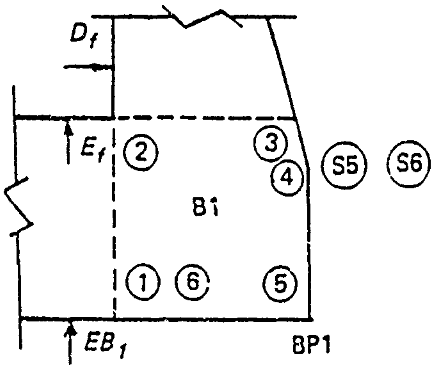
a. With heel



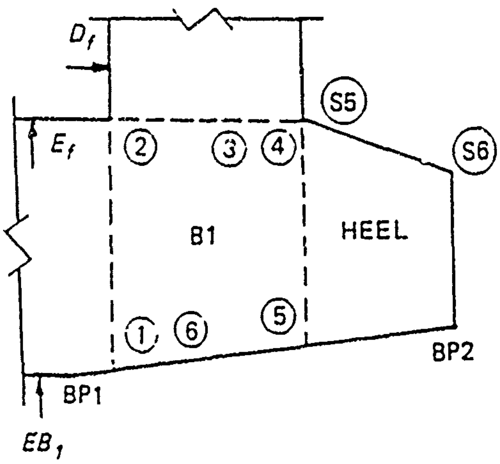
b. No heel



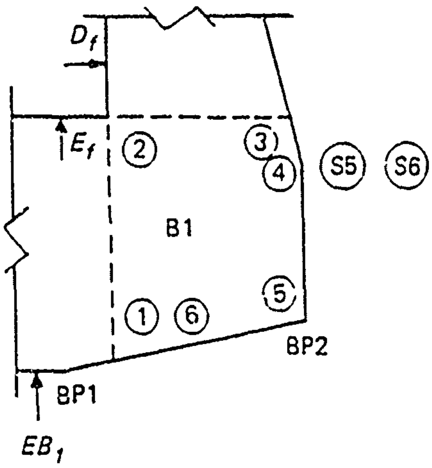
c. With heel



d. No heel



e. With heel



f. No heel

Figure 15. Example geometries of rigid block B1 for type 1 monoliths

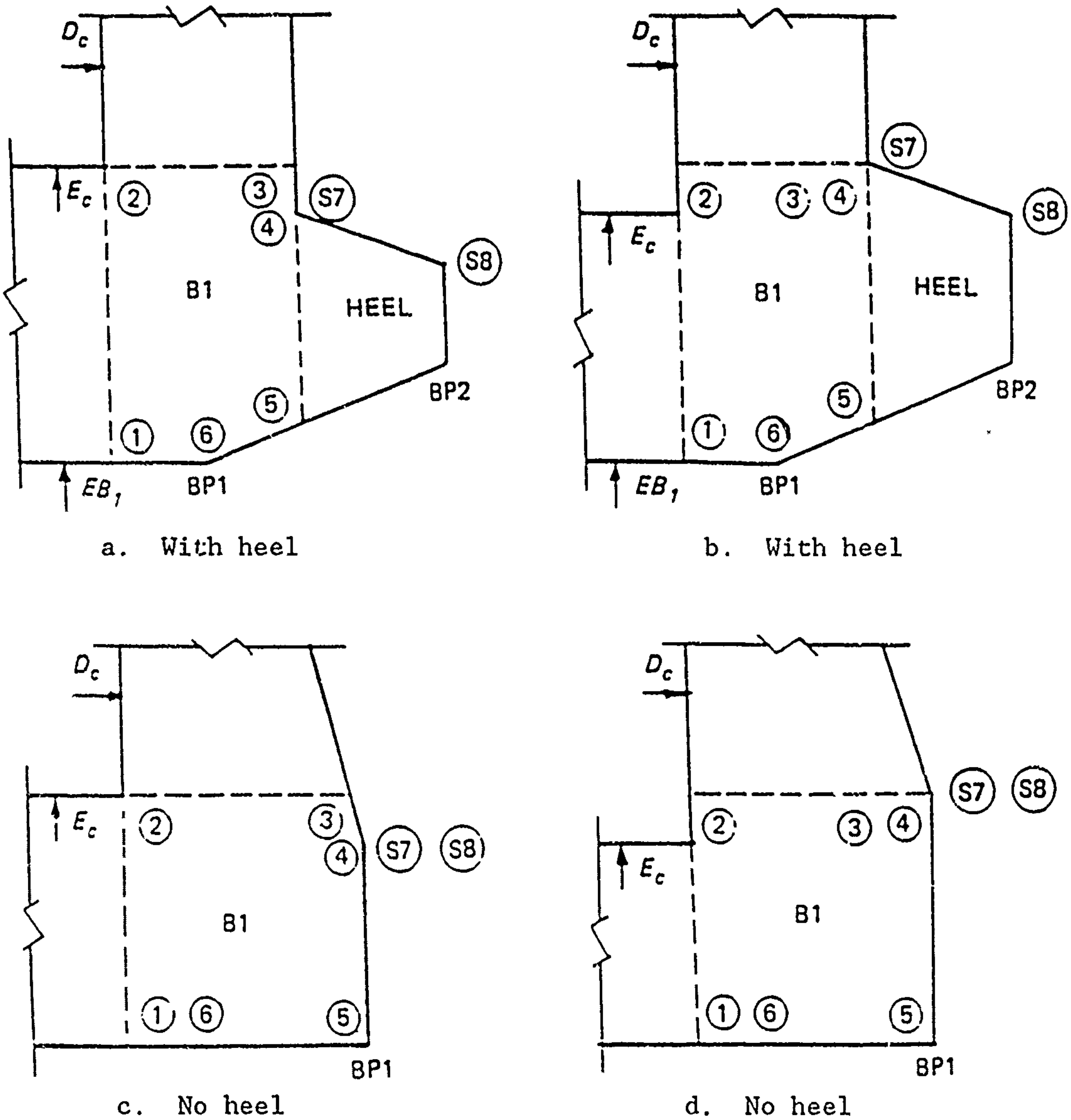


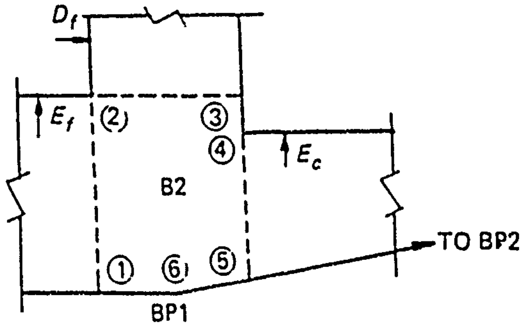
Figure 16. Example geometries for rigid block B1 for type 2 (or 3) monoliths (for types 31 and 33 monoliths, replace S7, S8 by S6, S7; for type 32 and 34 monoliths, S7, S8 by S4, S5)

<u>Block B2 (type 2 and type 3 monoliths)</u>

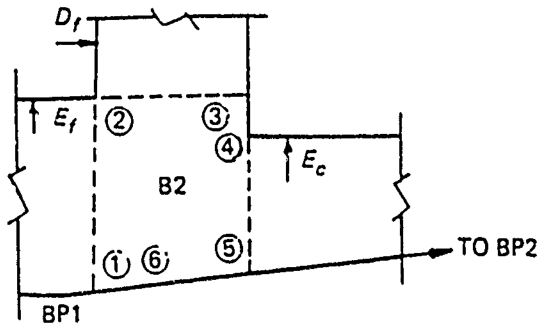
67. Block B2, types 2 and 3 monoliths, occupies the intersection of the base slab with the interior wall. Example geometries of block B2 are shown in Figure 17.

<u>Block B3 (type 2 monolith)</u>

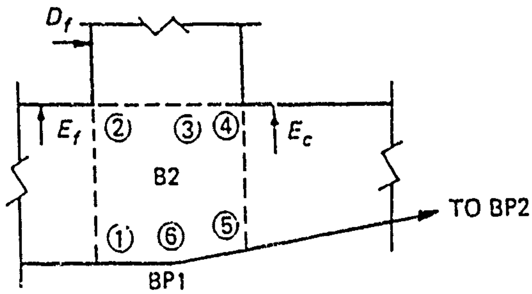
68. For a standard type 2 monolith, block B3 occupies the intersection of the interior culvert wall, the culvert roof slab, and the stem above the culvert. Example geometries for this case are shown in Figure 18. When stem



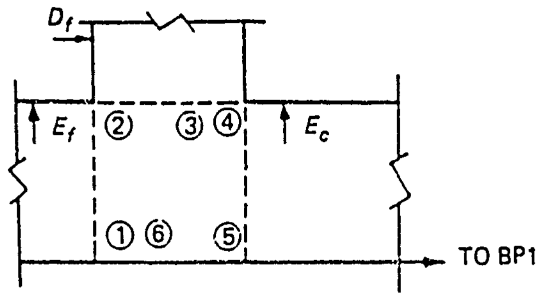
a. Two base points



b. Two base points



c. Two base points



d. One or two base points

Figure 17. Example geometries of rigid block B2 for type 2 or 3 monolith

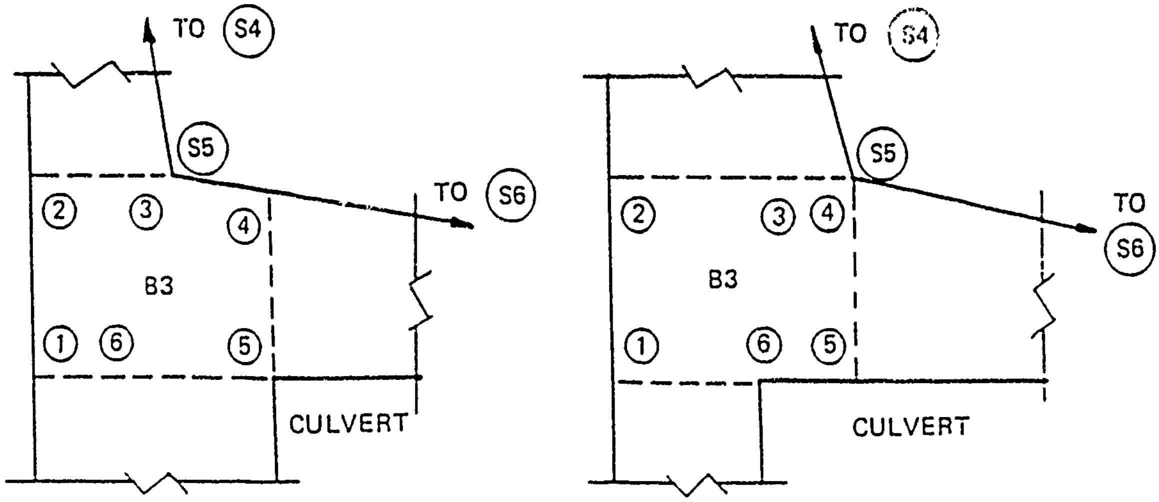


Figure 18. Example geometries for rigid block B3 for type 2 monoliths, standard case

points S5 and S6 coincide, block B3 occupies a rectangular area bounded by the stem face, the top of the culvert, and the elevation and distance to stem point S5 as shown in Figure 10.

Block B4 (type 2 monolith)

69. For a standard type 2 monolith, block B4 occupies the intersection of the culvert roof slab with the exterior culvert wall. The geometry of block B4 is shown in Figure 19.

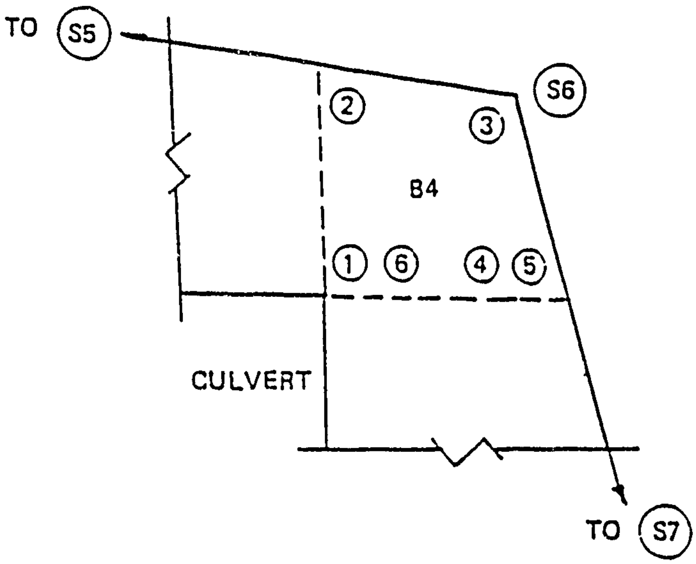


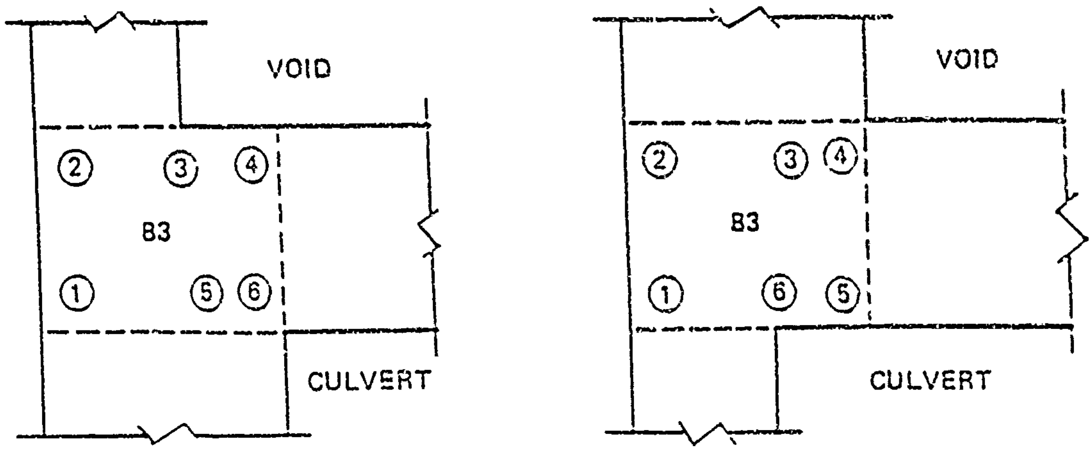
Figure 19. Rigid block B4 for type 2 monolith, standard case

Block B3 (type 3 monolith)

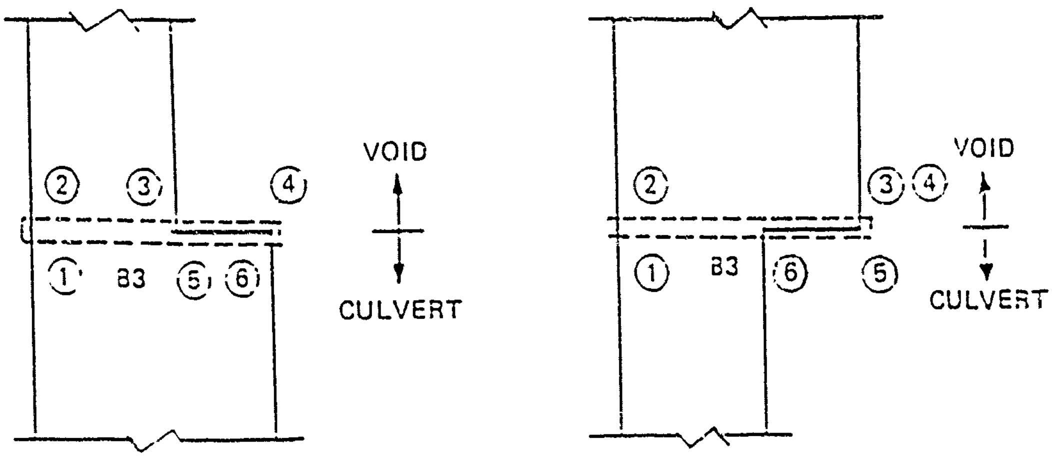
70. For types 31 and 33 monoliths, block B3 occupies the intersection of the interior culvert wall, the interior void wall, and the slab separating the culvert and void as illustrated in Figure 20a. Block B3 degenerates to a line for types 32 and 34 monoliths as shown in Figure 20b. For the latter case, all points on block B3 are at the same elevation.

Block B4 (type 3 monolith)

71. For types 31 and 33 monoliths, block B4 occupies the intersection of the exterior culvert wall, the exterior void wall, and the slab separating the culvert and void. Example geometries for these cases are shown in Figure 21a. For types 32 and 34 monoliths, block B4 degenerates to a line as illustrated in Figure 21b. In the latter case, all points are at the same elevation.



a. Type 31 or 33 monoliths



b. Type 32 or 34 monoliths

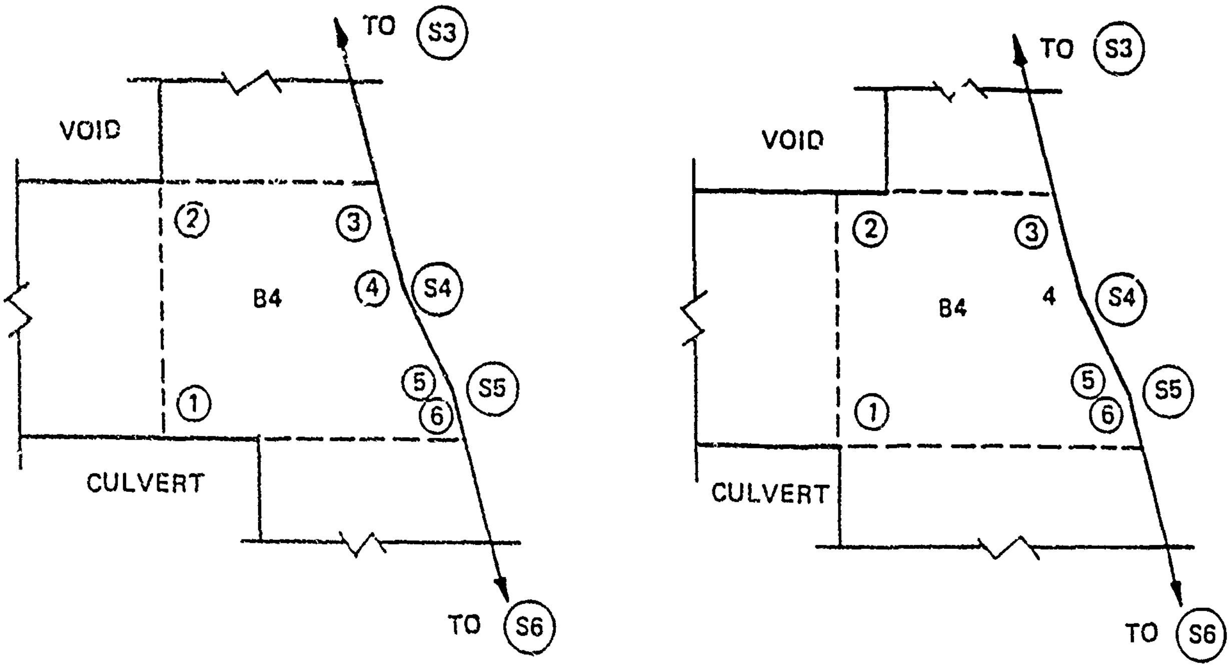
Figure 20. Example geometries for rigid block B3 for type 3 monoliths

<u>Block B5 (type 5 monolith)</u>

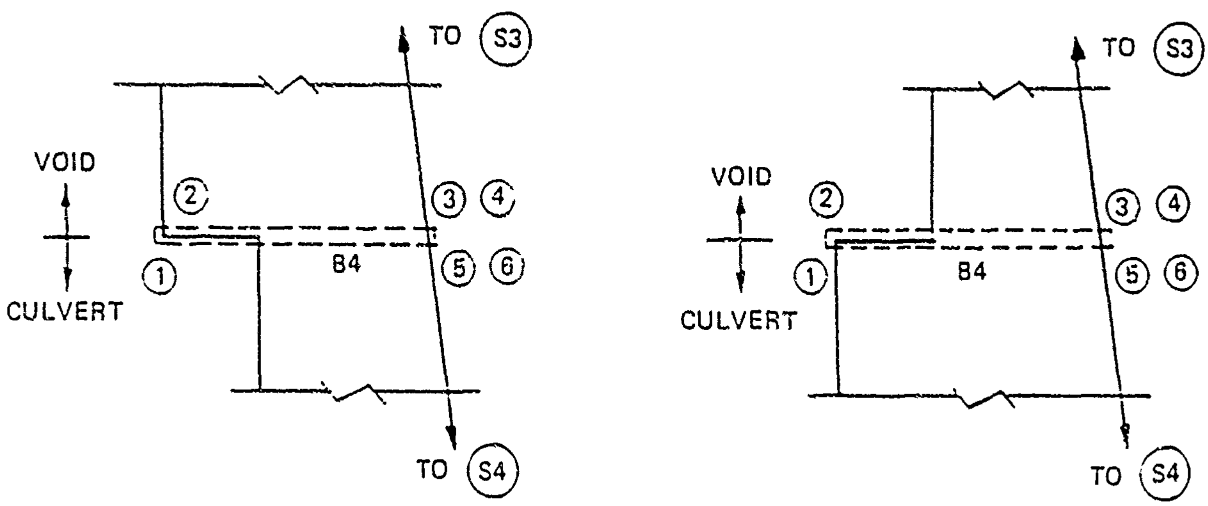
73. Block B5 occupies the rectangular area at the intersection of the interior void wall with the void roof slab for types 31 and 33 monoliths (Figures 11 and 13). Block B5 may be interpreted to degenerate to a line at the top of the interior void wall for types 32 and 34 monoliths.

<u>Block B6</u>

73. Block B6 is assumed to be present in all monoliths, being the topmost part of the stem for types 1 and 2, and the intersection of the exterior void wall and void roof slab (if present) for type 3 monoliths. Example geometries are shown in Figures 22 and 23. (Note: By supplying three closely spaced stem points (S1, S2, S3) at the top of the stem, block B6 may be caused



a. Type 31 or 33 monoliths



b. Type 32 or 34 monoliths

Figure 21. Example geometries for rigid block B4 for type 3 or type 4 monoliths

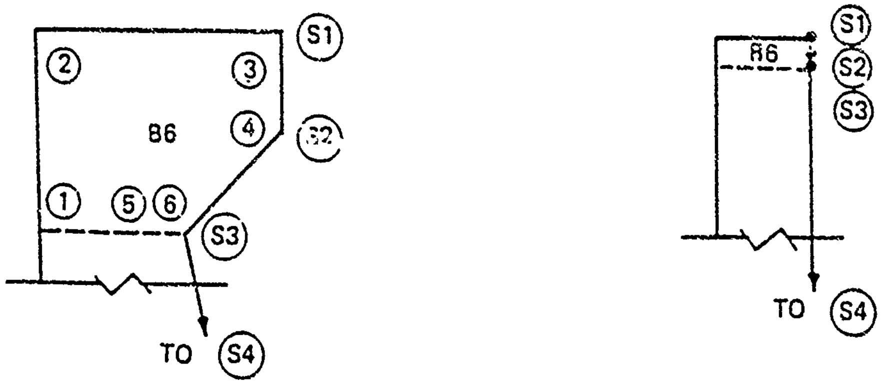
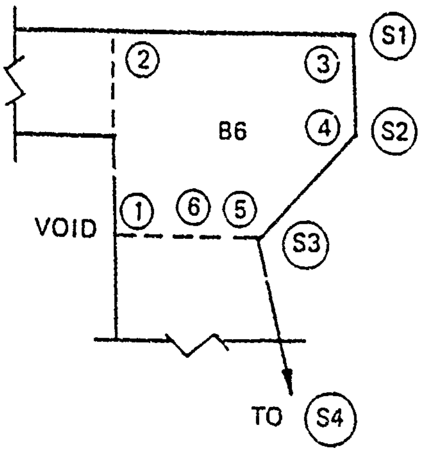
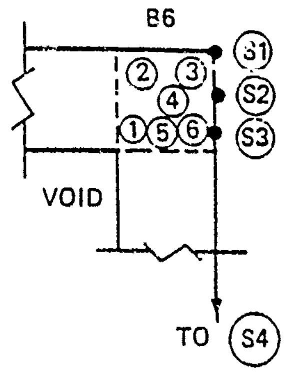


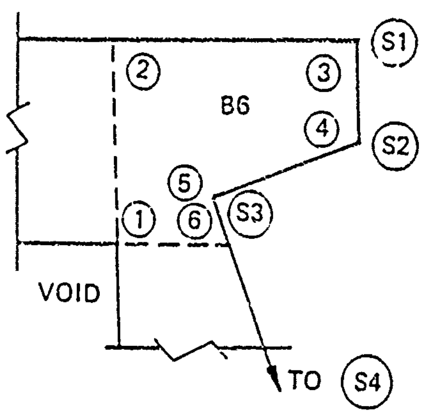
Figure 22. Example geometries for rigid block B6
for types 1 and 2 monoliths



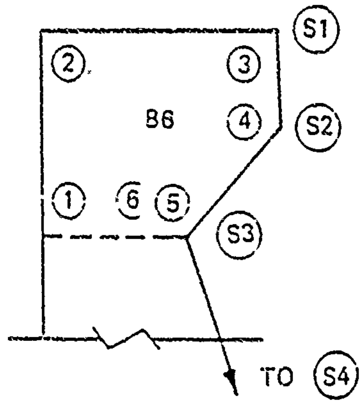
a. Type 31 or 32 monoliths



b. Type 31 or 32 monoliths



c. Type 31 or 32 monoliths



d. Type 33 or 34 monoliths

Figure 23. Example geometries for rigid block B6
for type 3 monoliths

to degenerate into a line for types 1, 2, 32, and 34 monoliths without stem protrusions.)

Rigid Blocks (C1 Through C9 Monoliths)

74. When a center stem is present, one of the center stem monoliths (C1 through C9) will define the associated rigid blocks. The size and shape of the rigid blocks are determined by the relative positions of the various input dimensions of the center stem. The geometry of each block is prescribed by elevations and distances from the centerline at points around the periphery of each block as follows in paragraphs 75 through 83.

Block CB1 (C1, C3, or C4 monolith)

75. Block CB1 in a C1, C3, or C4 monolith is at the intersection of the base slab and center stem. The rectangular area is defined by four points shown in Figure 24.

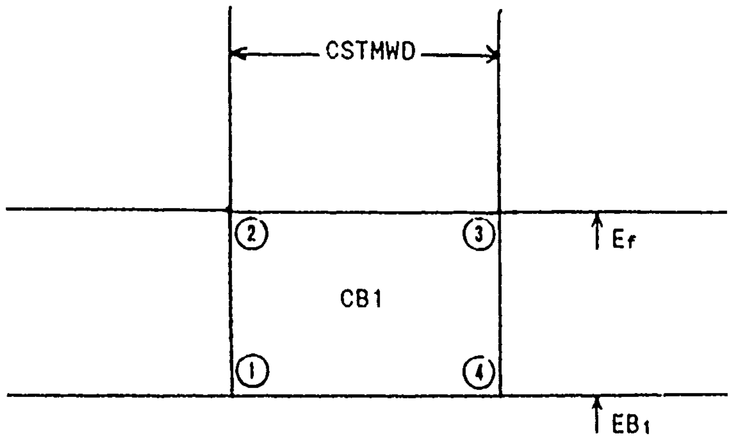


Figure 24. Block CB1, monoliths C1, C3, and C4

Block CB1 (C2, C5, or C6 monolith)

76. In a C2, C5, or C6 monolith, block CB1 occupies the intersection of the base slab, the center stem, and the culvert below the chamber floors. This block requires eight points as shown in Figure 25.

Block CB1 (C7, C8, or C9 monolith)

77. For a C7, C8, or C9 monolith, block CB1 occupies the intersection of the base slab, the center stem, and the floor of the two culverts. The geometry requires ten points and is shown in Figure 26.

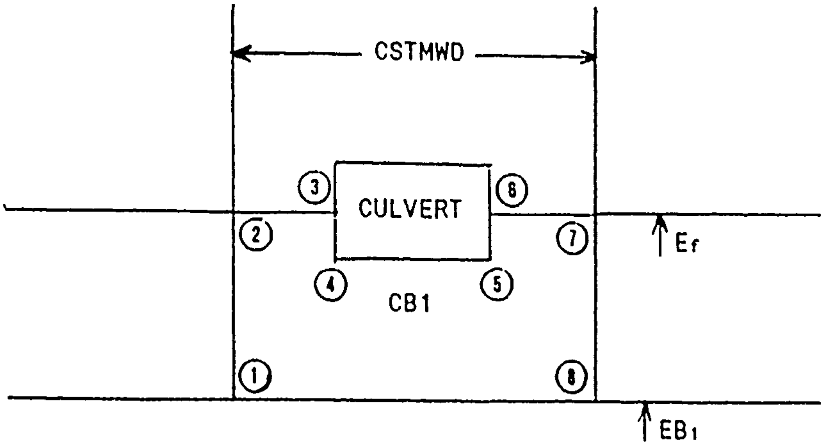


Figure 25. Block CB1, monoliths C2, C5, and C6

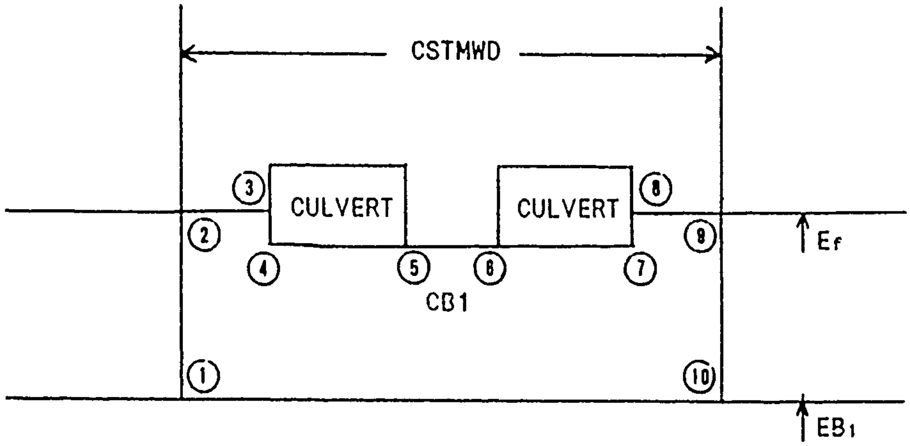


Figure 26. Block CB1, monoliths C7, C8, and C9

Block CB2 (C1 monolith)

78. In a C1 monolith, block CB2 is described by four points. The rectangular area is that portion of the center stem above the chamber floors. The geometry of this block is shown in Figure 27.

Block CB2 (C2 or C7 monolith)

79. Block CB2 in a C2 or C7 monolith is a rectangular area of that portion of the center stem located above the culvert(s) roof. Six points are required for a C2 monolith, while eight points are needed for a C7 monolith. Figure 28 shows the geometry for these cases.

Block CB2 (C3 or C4 monolith)

80. For a C3 or C4 monolith, block CB2 occupies the rectangular area of the center stem from chamber floors to the bottom of the void. The six required points are shown in Figure 29.

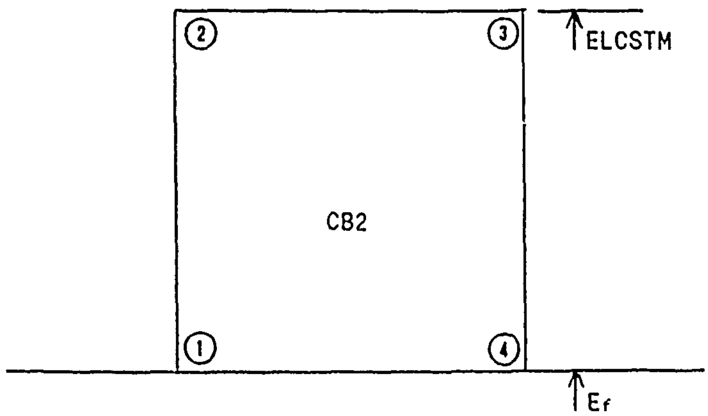
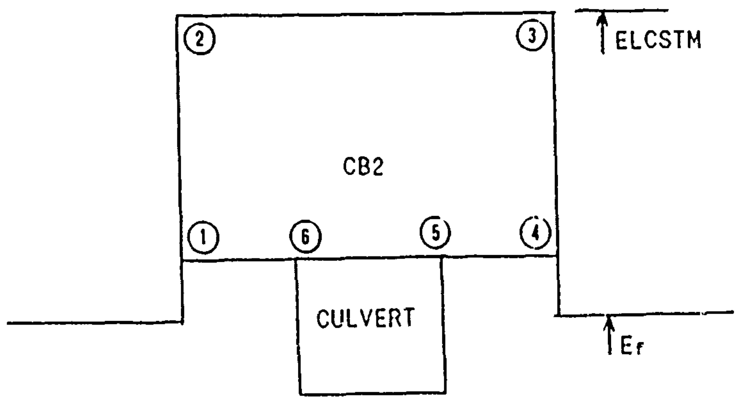
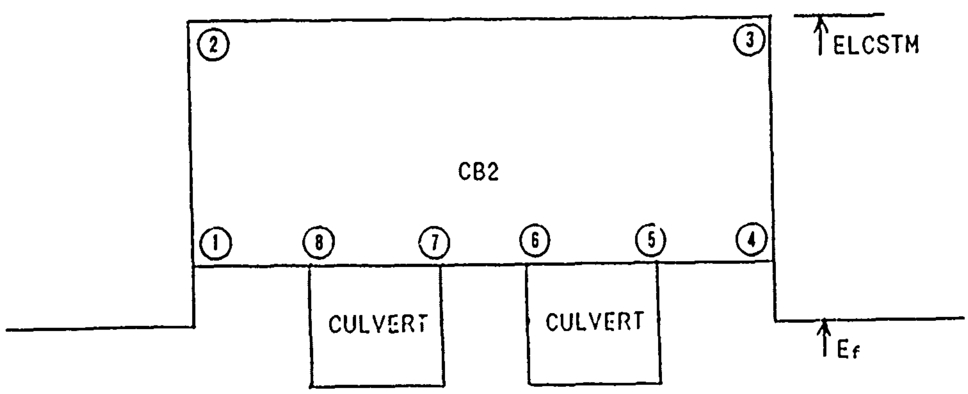


Figure 27. Block CB2, monolith C1



a. Block CB2, monolith C2



b. Block CB2, monolith C7

Figure 28. Examples of geometries for Block CB2

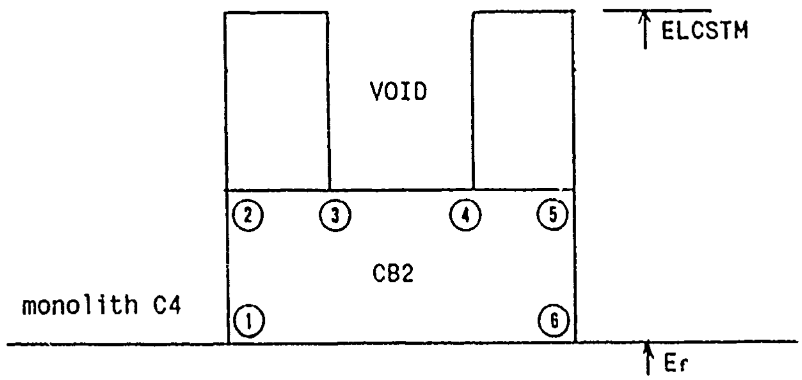


Figure 29. Block CB2, monoliths C3 and C4

Block CB2 (C8 or C9 monolith)

81. In a C8 or C9 monolith, 10 points describe block CB2. Figure 30 shows this block, the rectangular area of the center stem from the culvert roofs to the bottom of the void.

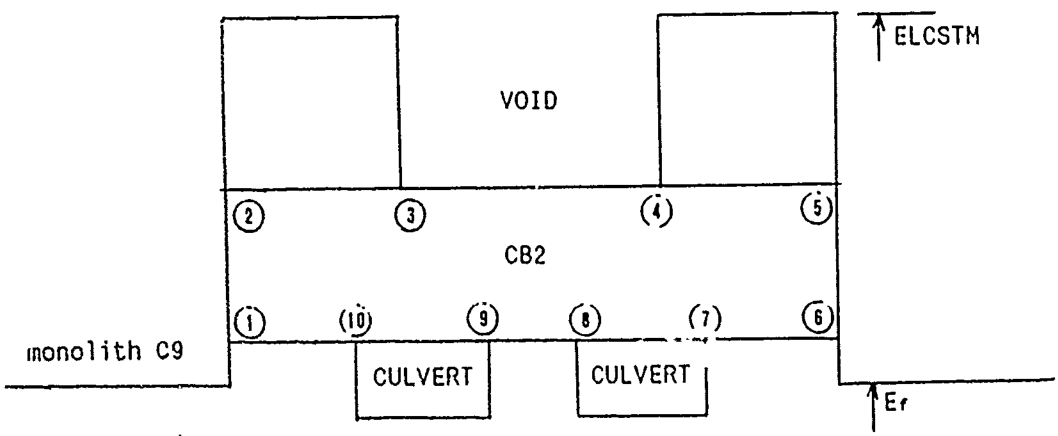


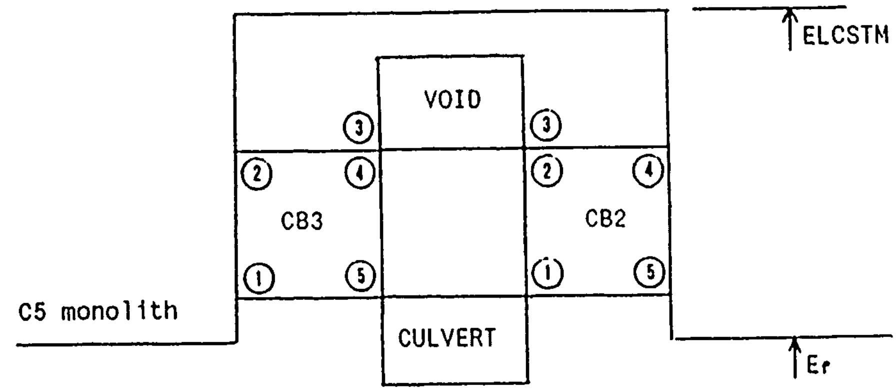
Figure 30. Block CB2, monoliths C8 and C9

Blocks CB2 and CB3 (C5 or C6 monolith)

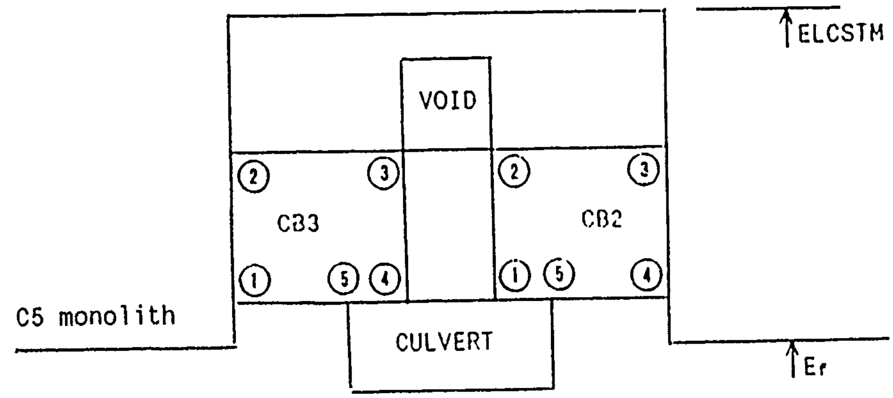
82. Both blocks CB2 and CB3 are described by five points in a C5 or C6 monolith. Blocks CB2 (rightside) and CB3 (leftside) occupy the intersection of the culvert wall and the void wall. Three different geometries, shown in Figure 31, are possible depending on the culvert and void widths.

Blocks CB4 and CB5
(C3, C5, or C8 monolith)

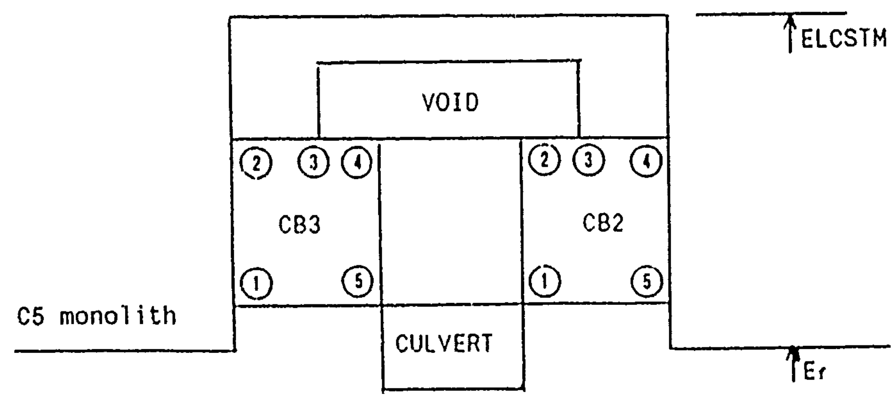
83. Block CB4 (rightside) and block CB5 (leftside) in a C3, C5, or C8 monolith occupy the intersection of the void wall and the void roof slab. Each block requires four points and this is shown in Figure 32.



a. VOIDWD = CULWID



b. VOIDWD < CULWID



c. VOIDWD > CULWID

Figure 31. Examples of geometries for Blocks CB2 and CB3 for C5 and C6 monoliths

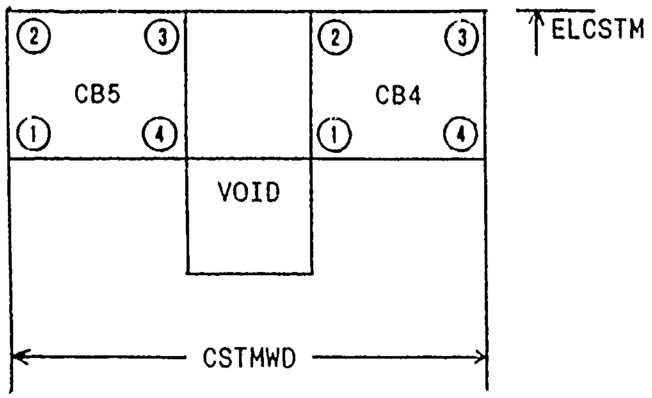


Figure 32. Blocks CB4 and CB5, monoliths C3, C5, and C8

Loads on Rigid Blocks

84. Any loads acting on the external surfaces of the rigid blocks, as well as the weight of the block, are converted into statically equivalent concentrated loads acting at the centroid of the rigid block.

Flexible Portions of the Structure

85. The following portions of the structure are assumed to be capable of distortion under the influence of external loads:

a. The base slab from the centerline (U-frame) or center stem face (W-frame) to the interior boundary of block B1 for a type 1 monolith or block B2 for types 2 and 3 monoliths.

b. The base slab under the culvert between blocks B2 and B1 for types 2 and 3 monoliths.

c. The heel beyond the exterior boundary of block B1 for all types, if present.

d. The interior culvert wall between blocks B2 and B3 for types 2 and 3 monoliths.

e. The interior culvert wall between blocks B1 and B4 (B3 for type 2, special case) for types 2 and 3 monoliths.

f. The culvert roof slab for type 2 standard monoliths and for types 31 and 33 monoliths.

g. The stem between blocks B1 and B6 for type 1 monoliths or between blocks B3 and B6 for type 2 monoliths.

h. The interior and exterior void walls in type 3 monoliths between blocks B3 and B5 and between blocks B4 and B6, respectively.

i. The void roof slab for types 31 and 32 monoliths.

j. The culvert walls between blocks CB1 and CB2 for monoliths C2 and C5 through C9.

k. The culvert roof slab between blocks CB2 and CB3 for monoliths C5 and C6.

l. The void walls between block CB2 and blocks CB4 and CB5 for monoliths C3 and C7.

m. The void walls for monolith C5 between blocks CB2 and CB4 and between blocks CB3 and CB5, respectively.

n. The void walls for monoliths C4, C6, and C9.

o. The void roof slab between blocks CB4 and CB5 for monoliths C3, C5, and C8.

Center-line* of Flexible Portions

86. The boundaries of the rigid blocks in contact with the flexible portions of the structure are in all cases horizontal or vertical lines. Likewise, the vertical center-line of the structure, the outside end of a heel (if present), a vertical line through an interior base point, and/or a horizontal line through an intermediate stem point (e.g., stem point S4 in a type 1 or 2 monolith) form additional horizontal and vertical boundaries at the ends of the flexible portions of the structure. The center-line of the flexible portion is defined to be the straight line at middepth of each portion. This center-line of the flexible portion is used to establish the locations of joints and to evaluate stiffness properties of the structural members in the model.

Joints in the Model

87. Joints in the frame model are established at the following locations in the structure:

a. At middepth of the base slab at the centerline.

b. At points on the center-line of the flexible portions of the base slab (and heel) immediately above the intersection of a pile with the base (discussion of piles, paragraph 111).

c. At an intermediate input base point, if the point falls within the limits of a flexible portic ..

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* The term "center-line" is used in a hyphenated form in paragraphs 86, 87, 89, 92, 93, 95 and 107 in reference to a particular geometric shape rather than the one-word form of centerline as used elsewhere in the report to be consistent with the term as used in the computer program CWFRAM.

d. At middepth of the extreme heel end (if heel is present).

e. At stem point S4 in types 1 and 2 monoliths.

f. At the centroid of each rigid block.

g. At the elevation of the void ties (discussion of void ties, paragraph 110).

Members in the Model

88. A structural member in the model is defined to be that portion of the structure between two joints.

Numbering of the Joints and Members

89. Integer number identifiers are assigned to the joints and members as follows:

a. Joints on the base are numbered beginning with (1) on the centerline and proceeding sequentially outward to the extreme end of the base.

b. Members in the base are numbered beginning with (1) for the member connected to the center-line joint and proceeding sequentially outward.

c. Joint numbers and member numbers are assigned to the structural components above the base slab depending on the type of monolith.

90. Joint and member identifiers for several monoliths are illustrated in Figures 33, 34, and 35.

Frame Member Dimensions

91. A member of the frame model may be connected to two intermediate joints (e.g., members 1 and 2 in Figure 33), to an intermediate joint at one end and to a rigid block at the other (e.g., members 6 and 7 in Figure 34), or to rigid blocks at each end (e.g., members 2 through 5 in Figure 34). In addition, the member cross section may be prismatic (e.g., member 1 in Figure 33) or may vary linearly (e.g., member 5 in Figure 34). In the following paragraphs, the evaluation of the member stiffness matrix and the assignment of various member characteristics are illustrated for a tapered member intersecting rigid blocks at each end.

92. A general tapered member is shown in Figure 36 (e.g., a base slab

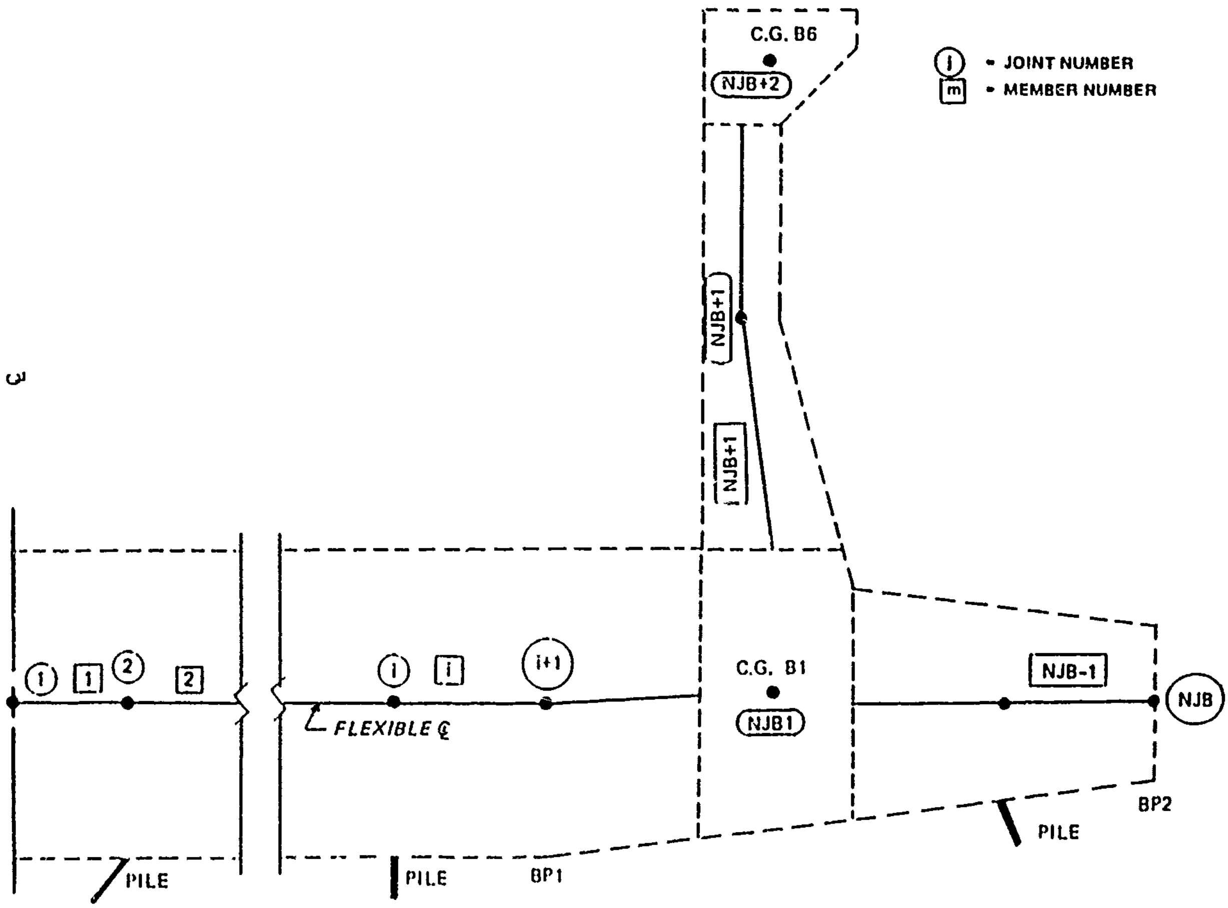


Figure 33. Joint and member numbers for type 1 monolith

member under the culvert for a type 2 or 3 monolith). The connectivity of this member to the joints is expressed as "member m goes from joint i to joint j." The member flexible center-line intersects the vertical boundaries of the rigid blocks (at midheight) at points a' and b'. The cross-sectional dimensions are assessed from the vertical dimensions H1 and H2 at points a' and b' as illustrated. Hence the member cross section will be rectangular at each end with dimensions B wide (B = thickness of the 2-D slice) by H1 deep at the left end and B by H2 at the rightend.

Member Flexible Length

93. A complex state of stress exists at the intersection of the member ends with the boundaries of the rigid blocks. Although the blocks have been described as rigid, there will be some deformation of the material at these interfaces. To account for this additional deformation, the flexible length

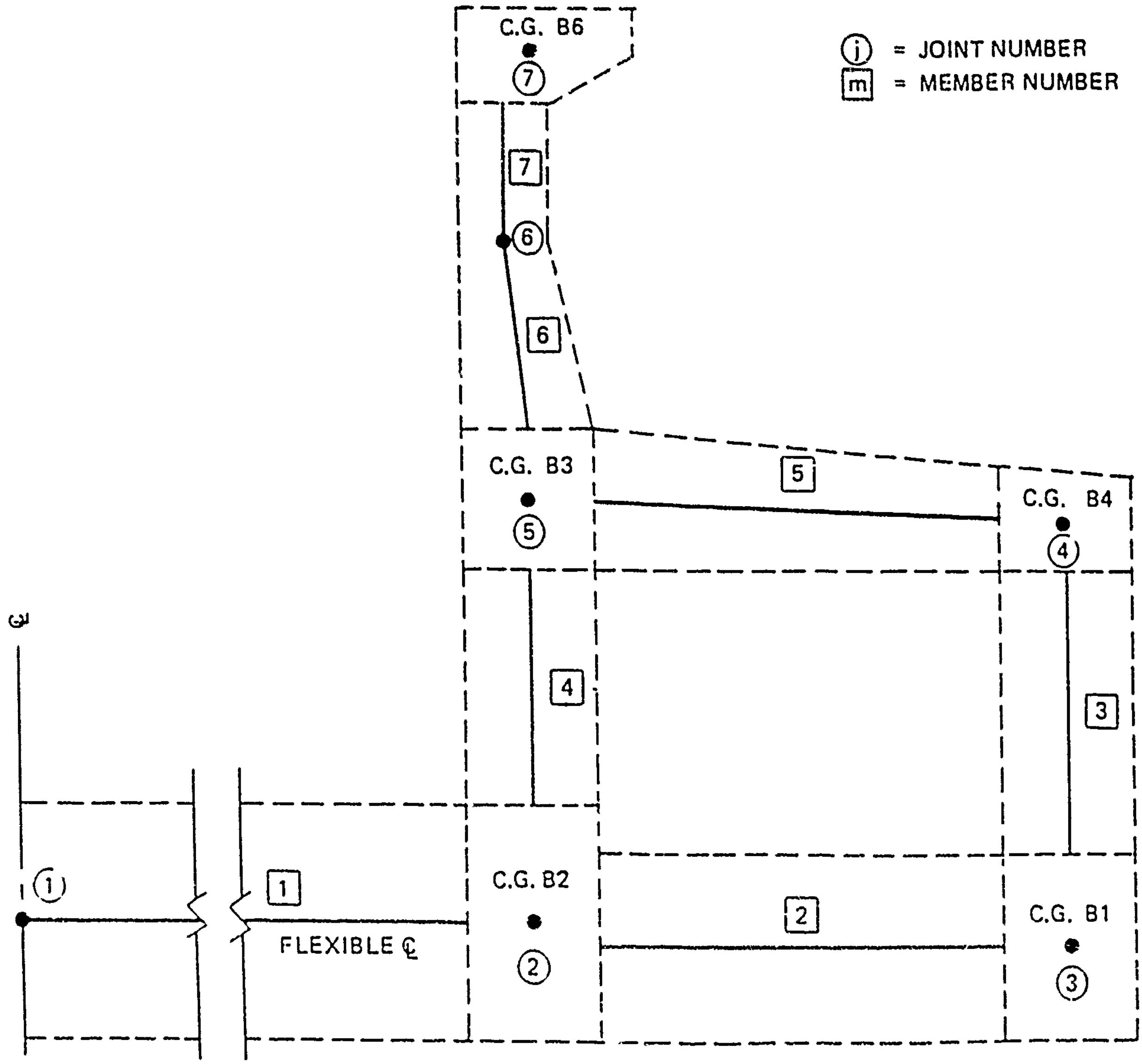


Figure 34. Example joint and member numbers for type 2 monolith, standard case, with soil support

of the member is extended into the blocks at each end to points a and b. The location of points a and b is established as follows: the horizontal distance from the rigid block center-line to the vertical interface is reduced by a user-supplied factor S ($0 \leq S \leq 1$). S = 0 extends point a or b to the vertical line through the block centroid; S = 1 places point a or b on the vertical interface (i.e., a, a′ and b, b′ coincide). The effect of the factor S is to shrink the size of the rigid blocks for flexibility assessment only; for other purposes (i.e., surface load transfer or piles intersecting the surface of a rigid block), the dimensions of the rigid blocks are unaffected.

94. For evaluation of the member stiffness matrix and fixed end forces,

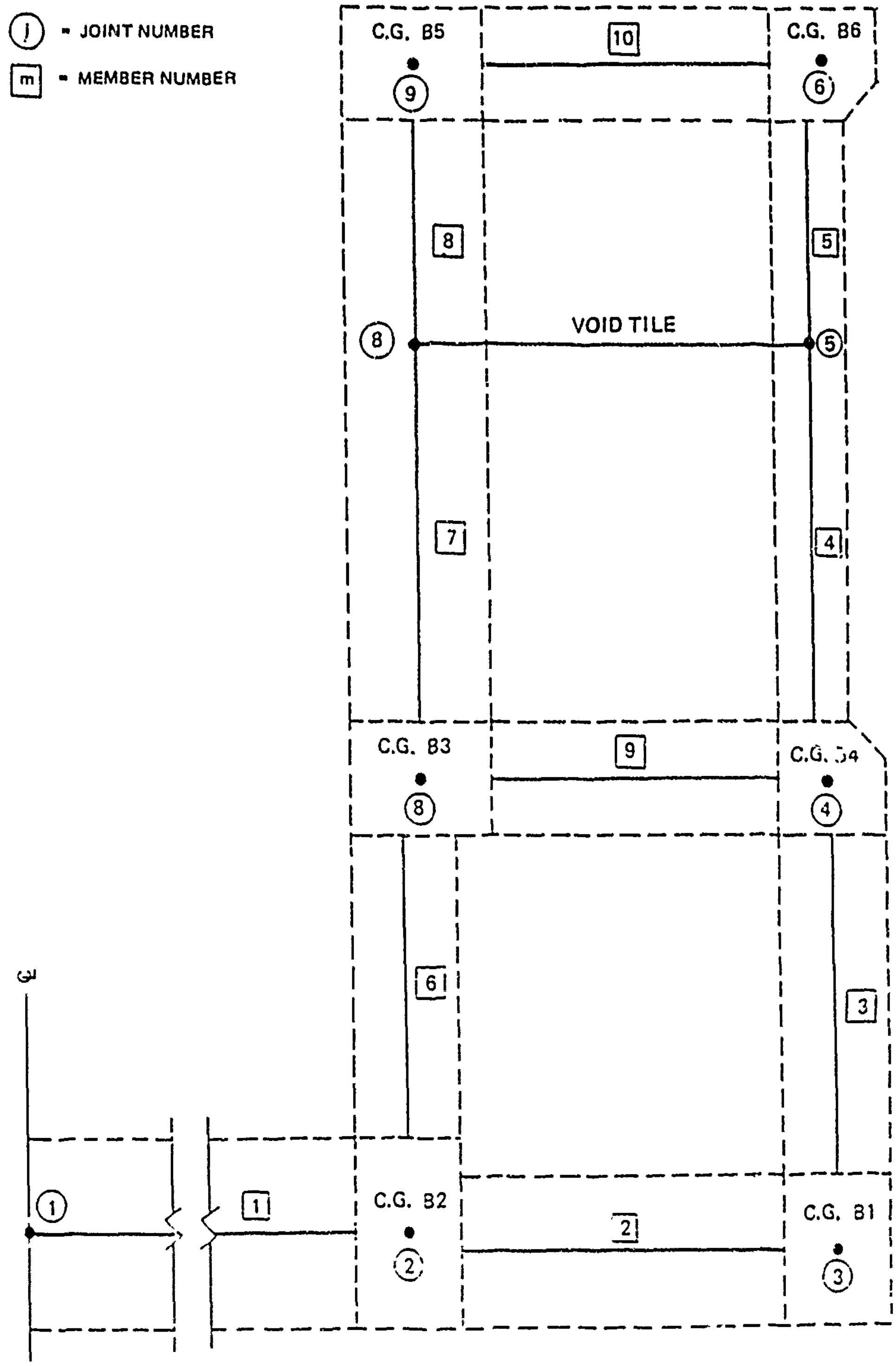


Figure 35. Example joint and member numbers for type 31 monolith with soil support

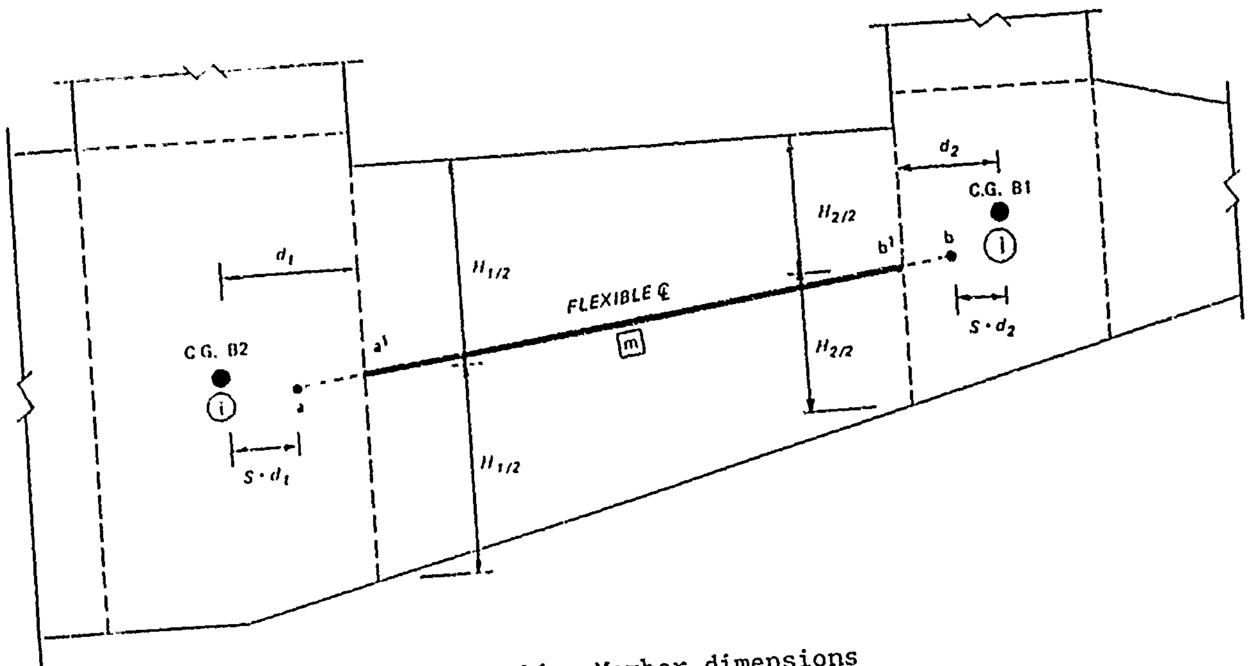


Figure 36. Member dimensions

the member is treated as a flexible section between points a and b (with cross sections at a and b as described in paragraph 92). The ends of the flexible length (a and b) are connected to the joints i and j (i.e., centroids of blocks) by rigid links as shown in Figure 37. This approximation, in effect,

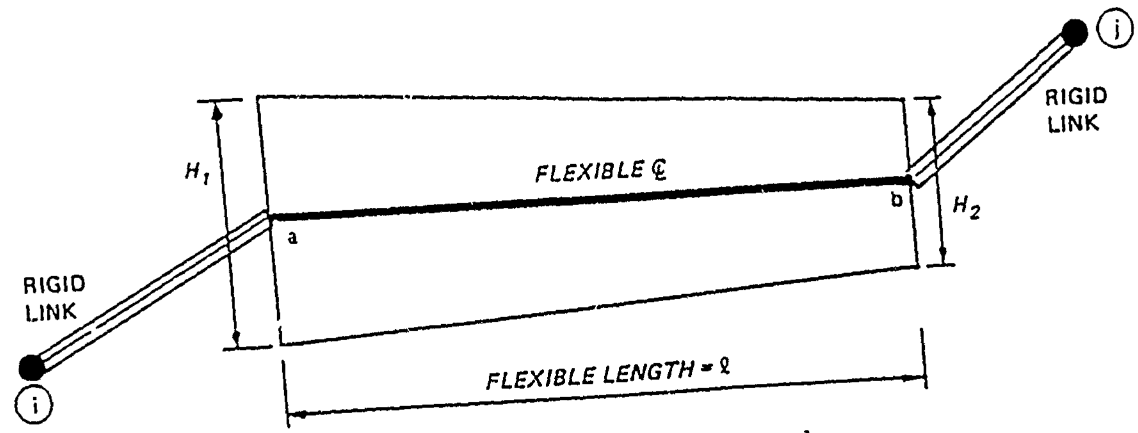


Figure 37. Equivalent frame member

distorts the actual member shape. The effect of this distortion is felt not to introduce significant errors for lightly tapered members or where the factor S is approximately equal to 1.

Member Stiffness Matrix

95. The member stiffness matrix for the member that is connected to joints i and j relates forces at joints i and j to displacements at joints i and j and accounts for the effects of the flexible length of the member and the effects of the rigid links at each end. This force-displacement relationship is initially established for a local right-hand Cartesian coordinate system (x, y, z with the origin at point a, the x-axis along the member flexible center-line positive toward point b, and the z-axis positive outward from the plane of the figure). Forces on the ends of the flexible length related to the local coordinate system are shown in Figure 38.

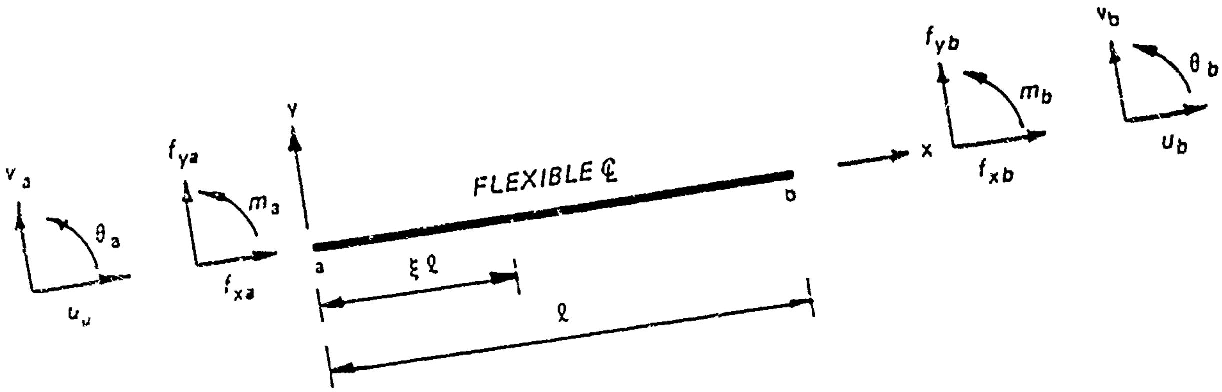


Figure 38. Member end forces and displacements in member coordinate system

96. At any point on the member ($\xi = x/l$), the internal stress resultants are related to the member end forces at point a by

$$P_\xi = -f_{xa}$$
$$V_\xi = f_{ya}$$
$$M_\xi = f_{ya}\,\xi - m_a$$

where

P_ξ = axial stress resulting at ξ

V_ξ = shear force at ξ

M_ξ = bending moment at ξ

97. Employing classical structural mechanics, the relationships between the forces and displacements at the end, point a, are expressed by

$$u_a = \frac{f_{xa}\ell}{E} \int_{\xi=0}^{\xi=1} \frac{d\xi}{A_\xi}$$

$$v_a = \frac{f_{ya}\ell^3}{E} \left(\int_{\xi=0}^{\xi=1} \frac{\xi^2 d\xi}{I_\xi} + \frac{E}{G\ell^2} \int_{\xi=0}^{\xi=1} \frac{d\xi}{A_{v\xi}} \right) - \frac{m_a\ell^2}{E} \int_{\xi=0}^{\xi=1} \frac{\xi d\xi}{I_\xi}$$

$$\theta_a = - \frac{f_{ya}\ell^2}{E} \int_{\xi=0}^{\xi=1} \frac{\xi d\xi}{I_\xi} + \frac{m_a\ell}{E} \int_{\xi=0}^{\xi=1} \frac{d\xi}{I_\xi}$$

where

A_ξ = cross-sectional area at ξ

$$= B\left[H_1(1 - \xi) + H_2(\xi)\right] = BH_1 \left(1 + \frac{H_2 - H_1}{H_1}\, \xi\right)$$

$$= A_o(1 + c\xi)$$

I_ξ = cross-sectional moment of inertia at ξ

$$= \frac{BH_1^3}{12} (1 + c\xi)^3 = I_o(1 + c\xi)^3$$

$A_{v\xi}$ = shear area at ξ

$$= \frac{A_o}{1.2} (1 + c\xi)$$

E = modulus of elasticity

G = shear modulus = $E/[2(1 + \nu)]$

ν = Poisson's ratio

98. Evaluation of the integrals in paragraph 97 yields

$$u_a = \frac{f_{xa}\ell}{EA_o} \frac{Ln(1 + c)}{c}$$

(Ln = Naperian logarithm)

$$v_a = \frac{f_{ya}\ell^3}{EI_o} \left\{ \frac{1}{c^3} \left[Ln\ (1 + c) - \frac{c(2 + 3c)}{2(1 + c)^2} \right] + \phi\, \frac{Ln\ (1 + c)}{c} \right\} - \frac{M_a\ell^2}{EI_o} \left[\frac{1}{2(1 + c)^2} \right]$$

$$\phi = \frac{1.2EI_o}{GA_o\ell^2}$$

$$\theta_o = - \frac{f_{ya}\ell^2}{EI_o} \left[\frac{1}{2(1 + c)^2} \right] + \frac{M_a\ell}{EI_o} \left[\frac{2 + c}{2(1 + c)^2} \right]$$

99. Inversion of the equations of paragraph 98 gives the following relationship between forces and displacements at point a.

$$\begin{Bmatrix} f_{xa} \\ f_{ya} \\ M_a \end{Bmatrix} = \begin{bmatrix} k_{11} & 0 & 0 \\ 0 & k_{22} & k_{23} \\ 0 & k_{32} & k_{33} \end{bmatrix} \begin{Bmatrix} U_a \\ V_a \\ \theta_a \end{Bmatrix}$$

$$(Note\ \ k_{32} = k_{23})$$

100. Finally, the entire member force-displacement relationship is expressed as:

$$\begin{Bmatrix} f_{xa} \\ f_{ya} \\ M_a \\ f_{xb} \\ f_{yb} \\ M_b \end{Bmatrix} = \begin{bmatrix} k_{11} & 0 & & -k_{11} & 0 & 0 \\ & k_{22} & k_{23} & 0 & -k_{22} & (k_{22}\ell - k_{23}) \\ & & k_{33} & 0 & -k_{23} & (k_{23}\ell - k_{33}) \\ & SYM & & k_{11} & 0 & 0 \\ & & & & k_{22} & (k_{23} - k_{22}\ell) \\ & & & & & (k_{22}\ell^2 - 2k_{23} + k_{33}) \end{bmatrix} \begin{Bmatrix} U_a \\ V_a \\ \theta_a \\ U_b \\ V_b \\ \theta_b \end{Bmatrix}$$

or $\underset{\sim}{f} = \underset{\sim}{k}'\underset{\sim}{u}$

101. For a prismatic member, c = 0, the stiffness coefficients become:

$$k_{11} = \frac{EA}{\ell}$$

$$k_{22} = \frac{12EI}{\ell^3(1 + 12\phi)}$$

$$k_{23} = \frac{6EI}{\ell^2(1 + 12\phi)}$$

$$k_{33} = \frac{4EI}{\ell}\ \frac{(1 + 3\phi)}{(1 + 12\phi)}$$

Transformation to Global Coordinates

102. Prior to imposing the effects of the rigid links, the member force-displacement relationship is transformed to relate force components at

ends a and b to displacement components in the global system. (The global coordinate system has x horizontal and y vertical; the global z-axis is coincident with the local z-axis.) This transformation results in :

$$\underset{\sim}{F}_{ab} = \underset{\sim}{R}^{T}\underset{\sim}{k}'\underset{\sim}{R}\underset{\sim}{U}_{ab}$$

or

$$\underset{\sim}{F}_{ab} = \underset{\sim}{k}\underset{\sim}{U}_{ab}$$

where

$\underset{\sim}{F}_{ab}$ = 6 × 1 vector of global force components at a and b

$\underset{\sim}{R}$ = transformation matrix

$$= \begin{bmatrix} c_x & c_y & 0 & 0 & 0 & 0 \\ -c_y & c_x & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & c_x & c_y & 0 \\ 0 & 0 & 0 & -c_y & c_x & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

c_x = cosine of the angle between local x and global x

c_y = cosine of the angle between local x and global y

$\underset{\sim}{R}^{T}$ = transpose of $\underset{\sim}{R}$

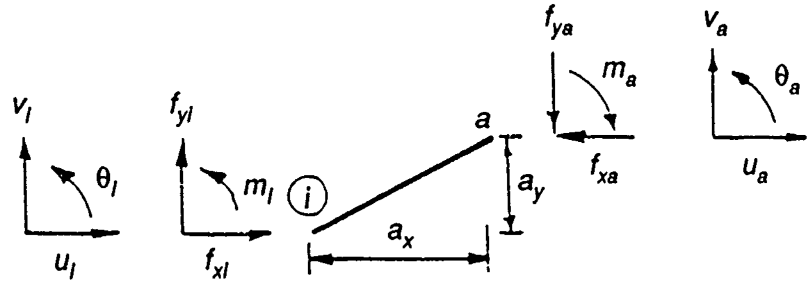
$\underset{\sim}{U}_{ab}$ = 6 × 1 vector of global displacement components at a and b

$\underset{\sim}{k}'$ = local stiffness matrix

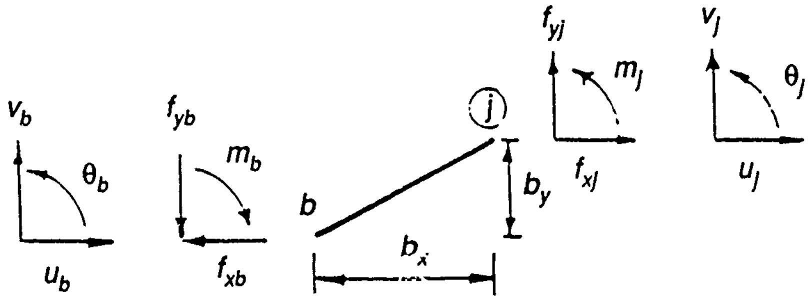
$\underset{\sim}{k}$ = global stiffness matrix

Effect of Rigid Links

103. Free-body diagrams of the rigid links at the ends of the member are shown in Figure 39. All force and displacement components, as well as the dimensions of the rigid links, are parallel to the global coordinates.



a. End a



b. End b

Figure 39. Free-body diagrams of rigid links

Equilibrium and kinematic analysis of the rigid links provides:

$$\begin{Bmatrix} U_a \\ V_a \\ \theta_a \\ U_j \\ V_j \\ \theta_j \end{Bmatrix} = \begin{bmatrix} 1 & 0 & -a_y & 0 & 0 & 0 \\ 0 & 1 & a_x & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & b_y \\ 0 & 0 & 0 & 0 & 1 & -b_x \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} U_i \\ V_i \\ \theta_i \\ U_j \\ V_j \\ \theta_j \end{Bmatrix}$$

or

$$\underset{\sim}{U}_{ab} = \underset{\sim}{D}\underset{\sim}{U}_{ij}$$

and

$$\begin{Bmatrix} F_{xi} \\ F_{yi} \\ M_i \\ F_{xj} \\ F_{yj} \\ M_j \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ -a_y & a_x & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & b_y & -b_x & 1 \end{bmatrix} \begin{Bmatrix} F_{xa} \\ F_{ya} \\ M_a \\ F_{xb} \\ F_{yb} \\ M_b \end{Bmatrix}$$

or

$$\underset{\sim}{F}_{ij} = \underset{\sim}{D}^T\underset{\sim}{F}_{ab}$$

104. Combination of the relationship of paragraphs 102 and 103 result in

$$\underset{\sim}{F}_{ij} = \underset{\sim}{D}^T\underset{\sim}{R}^T\underset{\sim}{k}'\underset{\sim}{R}\underset{\sim}{D}\underset{\sim}{U}_{ij} = \underset{\sim}{K}_{ij}\underset{\sim}{U}_{ij}$$

where $\underset{\sim}{K}_{ij}$ is the global stiffness matrix of the member connected to joints i and j , including the effect of rigid links.

Member Fixed End Forces

105. Due to the surrounding soil and water, the external surfaces of a member are subjected to distributed normal and tangential forces and possibly concentrated forces. These surface loads are resolved into components parallel and perpendicular to the flexible centerline. Only those forces that act on the member between the vertical boundaries of the rigid blocks (between points a' and b', Figure 36) are treated as member loads. The contributions of the member loads to fixed end forces are approximated as follows.

106. A member and surface loads are illustrated in Figure 40 for an

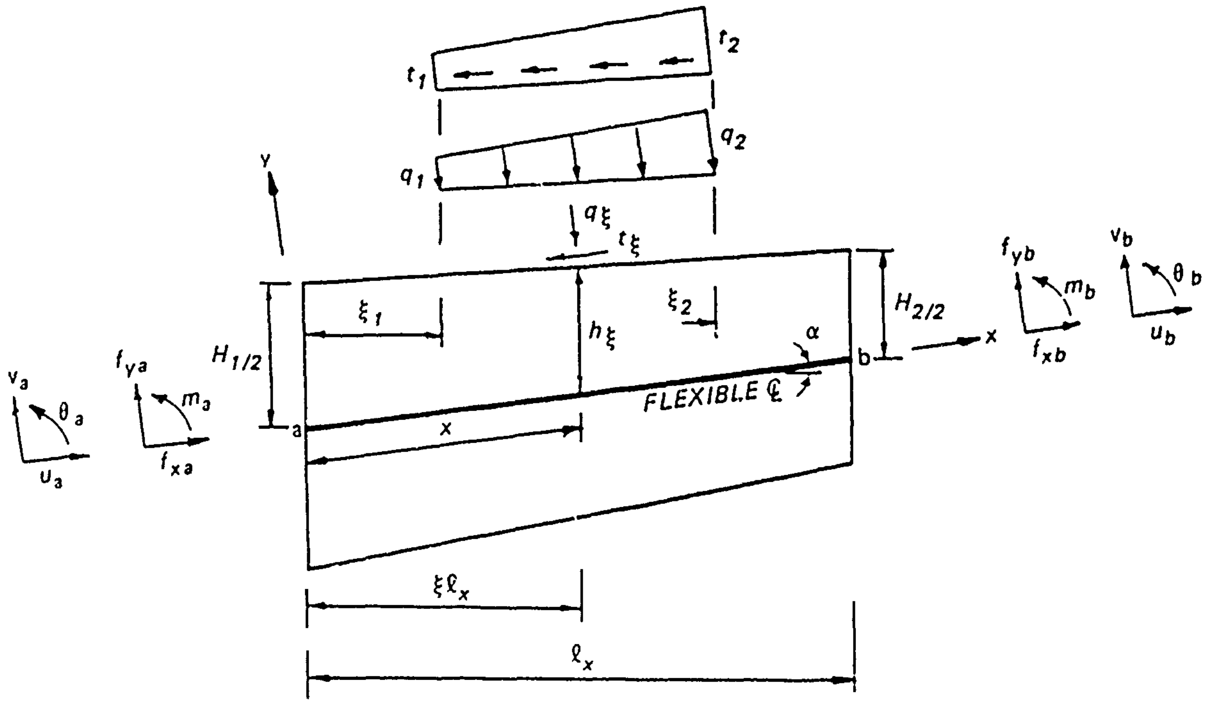


Figure 40. Member surface loads

essentially horizontal member. (For an essentially vertical member, interchange the horizontal and vertical descriptions in the following discussion.) The member is bounded by vertical lines through the ends of the flexible length (through a and b). Surface loads perpendicular (q) and parallel (t) to the member flexible centerline are shown on the top surface. These surface loads vary linearly from q_1, t_1 to q_2, t_2 between the limits of $\xi = \xi_1$ to $\xi = \xi_2$, where ξ is the dimensionless coordinate defined by $\xi = x/l$, x is the local coordinate of the generic point (p), and l is the flexible length of the member. The magnitude of the distributed loads at a generic point p′ on the surface immediately above (vertical) (p) are given by

$$q_\xi = q_1(1 - \xi) + q_2\xi$$

and

$$t_\xi = t_1(1 - \xi) + t_2\xi$$

and the vertical distance from p to p′ is given by

$$h_\xi = \frac{H_1(1 - \xi) + H_2\xi}{2}$$

If the displacements of point p are u , v , and 0 (components parallel to the local coordinate system), the displacements of the surface point p′ may be expressed as (ignoring the small deformations of the cross section)

$$u_s = u - \sigma h_\xi \cdot C_\alpha \theta$$
$$v_s = v + \sigma h_\xi \cdot S_\alpha \theta$$

where

σ = +1 for loads on top surface, = 0 for self weight of member, = -1 for loads on bottom surface

C_α = cosine of α

S_α = sine of α

The displacements of the generic point p may, in turn, be expressed in terms of the end displacements at a and b as

$$u = \psi_1(\xi)u_a + \psi_4(\xi)u_b$$

$$v = \psi_2(\xi)v_a + \psi_3(\xi)\theta_a + \psi_5(\xi)v_b + \psi_6(\xi)\theta_b$$

$$\theta = \frac{dv}{dx}$$

where $\psi_n(\xi)$ is an interpolation function of ξ to be discussed later. By the process of virtual work, the fixed end forces at a and b are evaluated for unit values of the end displacements as

$$f_{xa} = \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (u_a = 1 \text{ , others } 0)$$

$$f_{ya} = \ell_s \int_{\xi_1}^{\xi_2} q_\xi v_s d\xi + \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (v_a = 1 \text{ , others } 0)$$

$$M_a = \ell_s \int_{\xi_1}^{\xi_2} q_\xi v_s d\xi + \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (\theta_a = 1 \text{ , others } 0)$$

f_{xb} , f_{yb} , and M_b are obtained from expressions for $u_b = 1$, $v_b = 1$, and $\theta_b = 1$ with other displacements being equal to zero, respectively.

107. The interpolation functions $\psi_n(\xi)$ of paragraph 106 relate displacements at a generic point on the member center-line of an unloaded member to displacements at the ends of the member. Such functions are available only for a prismatic member in which shear distortions are negligible or where the distributed loads are uniformly distributed. A variety of structures have been analyzed to investigate the degree of approximation introduced by using prismatic member interpolation functions for the tapered members. It is felt that no appreciably significant errors are produced for the ordinary geometries usually encountered in U-frame or W-frame structures. However, no information is available related to the magnitude of errors in severely tapered members or for cases where loadings are significantly nonuniform. The interpolation functions used in the current analysis are

$$\psi_1 = 1 - \xi$$

$$\psi_2 = 2\xi^3 - 3\xi^2 + 1$$

$$\psi_3 = \left(\xi^3 - 2\xi^2 + \xi\right)\ell$$

$$\psi_4 = \xi$$

$$\psi_5 = -2\xi^3 + 3\xi^2$$

$$\psi_6 = \left(\xi^3 - \xi^2\right)\ell$$

108. The fixed end forces at ends of the flexible length are transformed to global coordinates and thence through the rigid links at the member ends to yield

$$\underset{\sim}{F}_{eij} = \underset{\sim}{D}^T \underset{\sim}{R}^T \underset{\sim}{F}_{eab}$$

where

$\underset{\sim}{F}_{eij}$ = 6 × 1 vector of fixed end forces at joints i and j in global coordinate directions

$\underset{\sim}{R}$ = 6 × 6 coordinate transformation matrix from paragraph 90

$\underset{\sim}{D}$ = 6 × 6 rigid link transformation matrix from paragraph 91

$\underset{\sim}{F}_{eab}$ = 6 × 1 vector of fixed end forces at the ends of the flexible length in local coordinate directions

109. The final relationship between member end forces, member end displacements, and member loads in the global coordinate system is

$$\underset{\sim}{F}_{ij} = \underset{\sim}{K}\underset{\sim}{U}_{ij} + \underset{\sim}{F}_{eij}$$

Void Tie Members

110. A facility for enforcing interaction between the vertical walls of the void opening is provided in the program. Fictitious horizontal structural members may be described as connecting the void walls at one or more elevations. These ties are assumed to behave as truss members (i.e., only

possessing axial stiffness). No guidance for the application of this facility is provided herein.

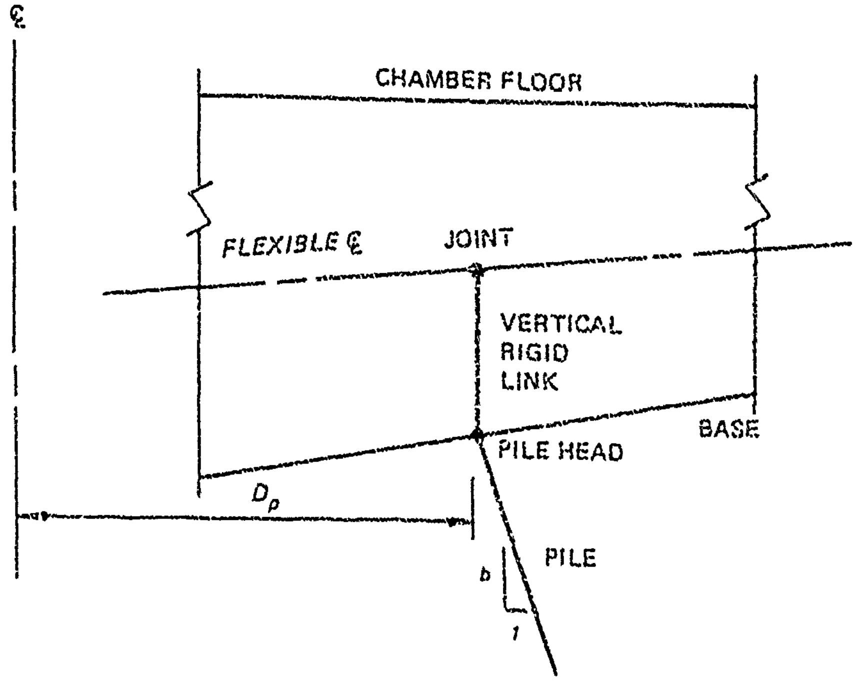
Pile Foundation

111. Piles attached to the base of the structure are treated as elastic elements that develop resistance proportional to the displacements at the pile head/structure base point of connection. The locations of pile head/structure base attachment points are provided by pile layout data that give the distance from the centerline to the pile head. The piles may be battered or vertical. A typical pile situation is shown in Figure 41.

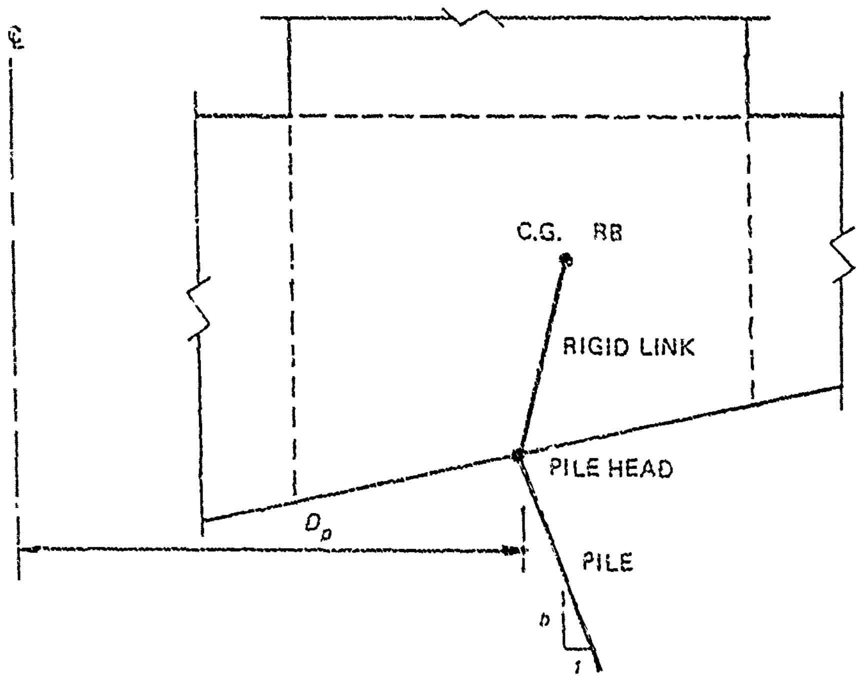
112. The distance, D_p , from the centerline to the pile head provided by pile layout data with base point distances and elevations determine the point at which the pile head is attached to the structure base. If the pile intersects a flexible portion of the structure base, a joint in the frame model is defined on the flexible centerline at a point immediately above the pile head. In this case, the pile head is assumed to be attached to the frame joint as illustrated in Figure 41a. If the pile intersects the base anywhere on the periphery of a rigid block, the pile head is connected to the joint at the rigid block centroid by a rigid link as shown in Figure 41b. (Note: Whe' the pile head intersects the flexible length of the base in the immediate vicinity of a rigid block, the flexible length of the base member between the "pile joint" and the rigid block may be extremely short and can lead to severe roundoff errors in the analysis. This condition should be avoided if at all possible.)

Pile Head Force-Displacement Relationships

113. Forces and displacements for a pile and the attendant rigid link are shown in Figure 42. The relationship between pile head forces and

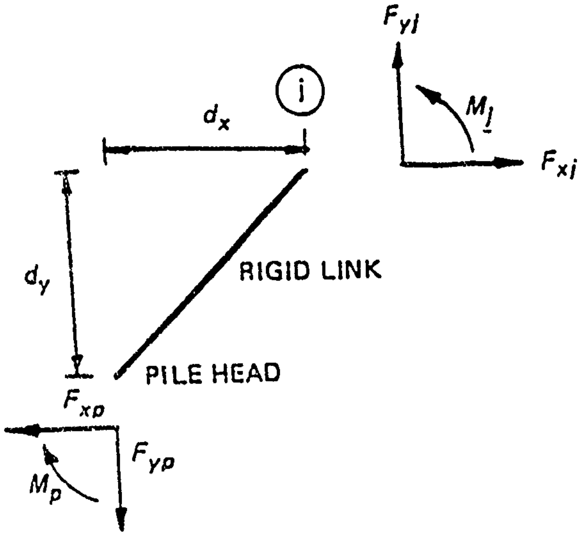


a. Pile head intersects flexible region

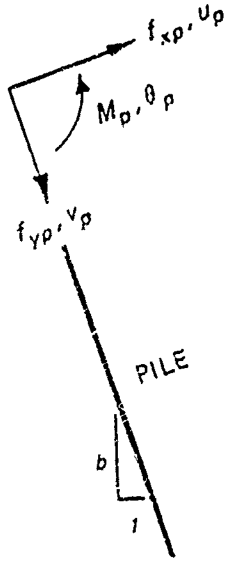


b. Pile head intersects rigid block

Figure 41. Pile-structure connections



a. Free-body diagram of pile rigid link



b. Pile head forces and displacements

Figure 42. Pile forces and displacements

displacements with components parallel and perpendicular to the axis of the pile is

$$\begin{Bmatrix} f_{xp} \\ f_{yp} \\ M_p \end{Bmatrix} = \begin{bmatrix} B_{11} & 0 & B_{13} \\ & B_{22} & 0 \\ SYM & & B_{33} \end{bmatrix} \begin{Bmatrix} u_p \\ v_p \\ \theta_p \end{Bmatrix}$$

or

$$\underset{\sim}{f}_p = \underset{\sim}{k}'_p \underset{\sim}{U}_p$$

where

f_{xp} = pile head shear force

f_{yp} = pile head axial force

M_p = pile head moment

B_{11}, B_{22}, B_{33}, B_{13} = pile head stiffness coefficients which may be supplied directly by the user or calculated internally by the program as discussed

u_p, v_p = translation components of displacement perpendicular and parallel to the pile axis, respectively

θ_p = pile head rotation

114. The above relationship is transformed to global coordinates for a battered pile by

$$\underset{\sim}{F}_p = \underset{\sim}{R}_p^T \underset{\sim}{k}'_p \underset{\sim}{R}_p \underset{\sim}{U}_p$$

where

$\underset{\sim}{F}_p$ = 3 × 1 vector of pile head forces parallel to global coordinates (horizontal and vertical)

$\underset{\sim}{R}_p$ = 3 × 3 transformation matrix

$$= \begin{bmatrix} C_1 & C_2 & 0 \\ -C_2 & C_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad C_1 = \frac{|b|}{\sqrt{1 + b^2}} \quad C_2 = \frac{|b|}{b} C_1$$

b = pile batter

$\underset{\sim}{U}_p$ = 3 × 1 vector of pile head displacements in global coordinate directions

115. Finally, the pile head force-displacement relationship is transformed through the rigid link to yield

$$\underset{\sim}{F}_{pj} = \underset{\sim}{D}_p^T \underset{\sim}{R}_p^T \underset{\sim}{k}_p' \underset{\sim}{R}_p \underset{\sim}{D}_p \underset{\sim}{U}_j$$

where

$\underset{\sim}{F}_{pj}$ = 3 × 1 vector of pile forces acting on joint j

$$\underset{\sim}{D}_p = \begin{bmatrix} 1 & 0 & dx \\ 0 & 1 & -d_y \\ 0 & 0 & 1 \end{bmatrix}$$

dx, dy = horizontal and vertical projections of pile rigid link

$\underset{\sim}{U}_j$ = 3 × 1 vector of joint j displacements

Pile Head Stiffness Matrix

116. As stated in paragraph 115, Equation 20, the pile head stiffness coefficients B_{11}, B_{22}, B_{33}, and B_{13} may be supplied as input. However, provision is made for evaluating these coefficients from pile/soil data. When the pile head stiffness matrix is calculated by the program, the following parameters are required as input data:

E = modulus of elasticity of pile material

A = pile cross-sectional area

I = pile cross-sectional moment of inertia

L = pile length

D_f = pile head fixity coefficient

k_A = axial stiffness coefficient

S_1, S_2 = soil stiffness coefficients for lateral resistance which varies linearly from S_1 at the pile head to $S_y = S_1 + S_2 y$ at any distance below the pile head

Axial Stiffness

117. The axial stiffness coefficient is evaluated as

$$B_{22} = k_A(EA/L)$$

Lateral Stiffness Coefficients for Fixed Head Piles ($D_f = 1$)

118. The lateral stiffness coefficients are determined from numerical solutions of the general differential equation

$$EI\left(d^4u/dy^4\right) + \left(S_1 + S_2y\right)u = 0$$

where E , I , S_1 , and S_2 are defined above; u is the lateral pile displacement and y is the distance along the pile axis. By definition, for a fixed head pile (see Figure 41 for notation)

$$B_{11} = \text{force } f_{xp} \text{ due to } u_p = 1 \text{ , } \theta_p = 0$$

$$B_{13} = \text{moment } M_p \text{ due to } u_p = 1 \text{ , } \theta_p = 0$$

$$B_{33} = \text{moment } M_p \text{ due to } u_p = 0 \text{ , } \theta_p = 1$$

Lateral Stiffness Coefficients for Pinned Head Pile ($D_f = 0$)

119. For a pinned head pile, M_p (and hence B_{13} , B_{33}) are identically zero. B_{11} is obtained by solution of the above differential equation for the case

$$u_p = 1 \text{ , } M_p = 0$$

Lateral Stiffness Coefficients for Partially Fixed Head Pile ($0 \leq D_f \leq 1$)

120. Effects of partial head fixity on the lateral stiffness coefficients are evaluated as:

a. The rotation $\theta_p = \theta_{po}$ for pinned head with $u_p = 1$, $M_p = 0$ is determined.

b. Coefficients B_{11} and B_{13} are obtained from the head forces due to $u_p = 1$, $\theta_p = (1 - D_f)\theta_{po}$.

c. Coefficient B_{33} is obtained from the head forces due to $u_p = 0$, $\theta_p = D_f * \theta_{po}$.

Vertical Piles on Centerline

121. When the pile system is symmetric about the centerline, only the data describing the piles on the rightside of the structure are required as input and the computer program automatically generates a mirror image description for the piles on the leftside. An ambiguity arises in a symmetric system when a vertical pile is attached at centerline of the structure where a strict mirror image would result in doubling the effects of vertical centerline piles. In the computer program, the stiffness effects of vertical centerline piles in symmetric systems are evaluated for only a single pile and one-half of the pile stiffness matrix is assigned to each side of the structure.

Method of Solution

122. The force-displacement relationships for the frame members and piles (if present) are assembled into a force-displacement relationship of the form

$$\underset{\sim}{F} = \underset{\sim\sim}{kU} + \underset{\sim}{F_o}$$

where, for a system with n joints,

$\underset{\sim}{F}$ = $3n \times 1$ vector of loads applied directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressures

$\underset{\sim}{k}$ = $3n \times 3n$ structure stiffness matrix composed of structure member stiffness matrices, pile head stiffness matrices and void tie stiffnesses

$\underset{\sim}{U}$ = 3n × 1 vector of joint displacements

$\underset{\sim}{F}_e$ = 3n × 1 vector of member fixed end forces

The 3n simultaneous equations are solved by Gauss elimination, for the joint displacements. Known displacements are substituted into the various member end force-displacement and pile head force-displacement relationships to obtain member end forces and head forces.

Restraint of Rigid Body Motions

123. In pile-supported systems, the piles act as linearly elastic supports that inhibit rigid body motions of the system and no additional support specifications are necessary. However, in the soil-supported system, once equilibrium of all forces has been established, there are no supports to prevent rigid body displacements. For a soil-supported system, all displacements of the joint on the structure centerline are specified to be zero. Consequently, the displacements obtained from the frame analysis of soil-supported systems must be realized to be relative values only.

PART VI: COMPUTER PROGRAM

General Description of the Program

124. The computer program, CWFRAM, that implements the foregoing procedures is written in FORTRAN language for execution on computer systems employing word lengths equivalent to 15 decimal digits. Calculations during the equilibrium analysis are not particularly sensitive to computer word length. However, evaluation of component stiffness matrices and solution of the simultaneous equations in the frame analysis phase may require double precision computations for machines with word lengths of fewer than 15 decimal digits.

125. The program is written for operation in a time-sharing environment. Although program prompts must be answered interactively from the user terminal, the experienced user will take advantage of the permanent file capabilities provided for input and output data. Because the output from the program may be extensive, it may be advantageous for the user to direct output to a permanent file and to recover the output data with a high-speed printer after execution of the program is terminated.

Input Data

126. Input data (Appendix A) may be supplied from the user terminal or from a predefined data file. When data are supplied during execution from the terminal, program prompts are provided to indicate the type and amount of data to be provided.

127. Input data are divided into sections and subsections. This is shown in Figure 43.

128. Data sections I, II, III-A, and V-A need only be entered once, since these data apply to the entire structure. Other data sections are interpreted as applying to the rightside or leftside of the structure. If symmetric conditions exist for both sides of the structure, the data are designated as being applicable to both sides. In this case, data need only be entered for the rightside and the program automatically generates mirror image data for the leftside. When different conditions exist for the two sides, data are entered for the rightside first and immediately followed by the description for the leftside.

I. Heading[1]
II. Mode of Operation[1]
III. Structure Data[1]
    A. Floor Data[1]
    B. Base Data[1]
    C. Outside Stem Data[1]
    D. Outside Stem Culvert Data[2]
    E. Outside Stem Void Data[2]
        1. Void Tie Data[2]
    F. Center Stem Data[2]
    G. Center Stem Culvert Data[2]
    H. Center Stem Void Data[2]
        1. Void Tie Data[2]
IV. Backfill Data[2]
    A. Soil Layer Data[3], or
    B. Backfill Soil Pressure Data[3]
V. Base Reaction Data[1]
    A. Soil Data[3], or
    B. Pile Data[3]
        1. Layout Data[1]
        2. Pile/Soil Properties[3], or
        3. Pile Head Stiffness Matrices[3]
        4. Batter Data[2]
        5. Allowables Comparison Data[2]
VI. Water Data[2]
    A. External Water Data[2]
        1. Water Elevations[3], or
        2. Water Pressure Data[3]
    B. Uplift Water Data[2]
        1. Water Elevations[3], or
        2. Water Pressure Data[3]
    C. Internal Water Data[2]
VII. Additional Load Data[2]
    (Distributed or Concentrated)
    A. Outside Stem Loads[2]
        1. Exterior Stem Loads[3],
        2. Interior Stem Loads[3], or
        3. Top Stem Loads[3]
    B. Floor Loads[2]
    C. Base Loads[2]
    D. Center Stem Loads[2]
        1. Face Stem Loads[3], or
        2. Top Stem Loads[3]
    E. Earthquake Accelerations[2]

---

[1] Data section is required.
[2] Optional data may be omitted entirely.
[3] One of the subsections is required.

Figure 43. Section and subsections of input data.

129. During the input phase, from a file or from the user terminal, data values are checked for consistency of dimensions and completeness. If an error is encountered during input from a file, the user is notified and execution of that problem is terminated. If an error is detected during entry from the terminal, the user is offered the opportunity to revise the last entry that produced the error.

Data Editing

130. After the input phase is completed, from a file or from the terminal, the user is offered the opportunity to edit (revise) the current input data. Any data section or subsection selected for editing must be entered in its entirety.

Data File Creation

131. After any data entry from the terminal, initial or after editing, the user has the option of saving the existing input data in a permanent file in the data file format. Because the program prompts for entry from the terminal are lengthy, an experienced user will usually find it more efficient to perform editing of an input file externally from the program.

Output Data

132. Output data may be directed to a permanent file, to the user terminal, or to both simultaneously. The following output sections are available.

Echoprint of the input data

133. The echoprint of input data is a tabular presentation of the numerical input including appropriate headings and units. This section of the output is optional.

Results of equilibrium analysis

134. This section presents pressures generated by the program or interpolated from user input at key points on the structure, resultants of the loads on each side of the structure, and net resultants of all loads.

Frame model data

135. This section provided data regarding the 2-D frame model developed by the program in the frame analysis mode. Included are data defining the rigid blocks, coordinates of the joints of the model, member connectivity, member dimensions, and pile stiffness coefficients if a pile foundation is present.

Results of the frame analysis

136. This section incorporates the calculated displacements for each joint in the structure, forces at the ends of the flexible length for each member, displacements and pile head forces for a pile-supported structure, and results of the pile allowables comparisons. (Note: See Appendix A for a discussion of pile allowables comparisons.)

Detailed member forces

137. Following the frame analysis, the user may obtain a tabulation giving the variation of axial force, shear force, and bending moment within any member of the structure selected. This section of the output is optional.

Program Verification

138. The pressures (backfill, water, soil base pressures) generated by the program have been verified by hand computations for a variety of systems. Wherever possible, the results (deflection, axial force, shear force, and bending moment) of the frame analysis have been calculated by other processes for comparison. For example, the internal force at the juncture of the base slab and outside stem face for a soil-supported structure can be obtained from a static analysis. Similarly, deflections for the section of the base slab from the centerline (U-frame) or center stem face (W-frame) to the juncture of the base slab and outside stem face for a soil-supported system can be obtained from classical beam analysis. For statically indeterminate systems, solutions have been obtained using the general-purpose computer program GTSTRUDL. Results using GTSTRUDL for several of the example solutions presented in Part VII are given in Appendix B.

PART VII: EXAMPLE SOLUTIONS

139. The examples presented below are intended only to illustrate the use of the program and are not to be interpreted as a guide for application of the program.

Example 1--Type 1 Monolith

140. The symmetric, soil-supported system is shown in Figure 44. All s il and water data were provided by elevations and unit weights. The additional upward distributed load on the base might represent the effects of seepage parallel to the longitudinal axis of the structure.

Data input

141. Input data were entered from the terminal during execution as shown in Figure 45. The echoprint of the data (optional), Figure 46, provides a tabulation of the input data with appropriate labels and units. A plot of the input geometry generated by the program is included in Figure 46. Following successful data entry, terminal input was saved in a file. The input file generated by the program shown in Figure 47 was retrieved following termination of the run. Because the system is symmetric, only the rightside of the structure need be described.

Results of equilibrium analysis

142. The results of the equilibrium analysis are shown in Figure 48. Backfill soil and water data have been converted to pressures as shown in Section II.A. of this figure. These pressures are determined at location of changes in the geometry of the structure, at the elevations of soil layer boundaries, and at ground-water elevation. When a discontinuity in pressure occurs (e.g., at soil layer boundaries), two values of pressure at that elevation are given, one immediately above the elevation and one immediately below. In this case, the two values given at elevation (el) 44 ft are the result of the horizontal top surface of the heel: the first for the point nearer the structural centerline, and the second for the point at the end of the heel. Otherwise, the pressures do not affect the upward sloping section of the base. A plot of backfill and external water pressures generated by the program is included in Figure 48.

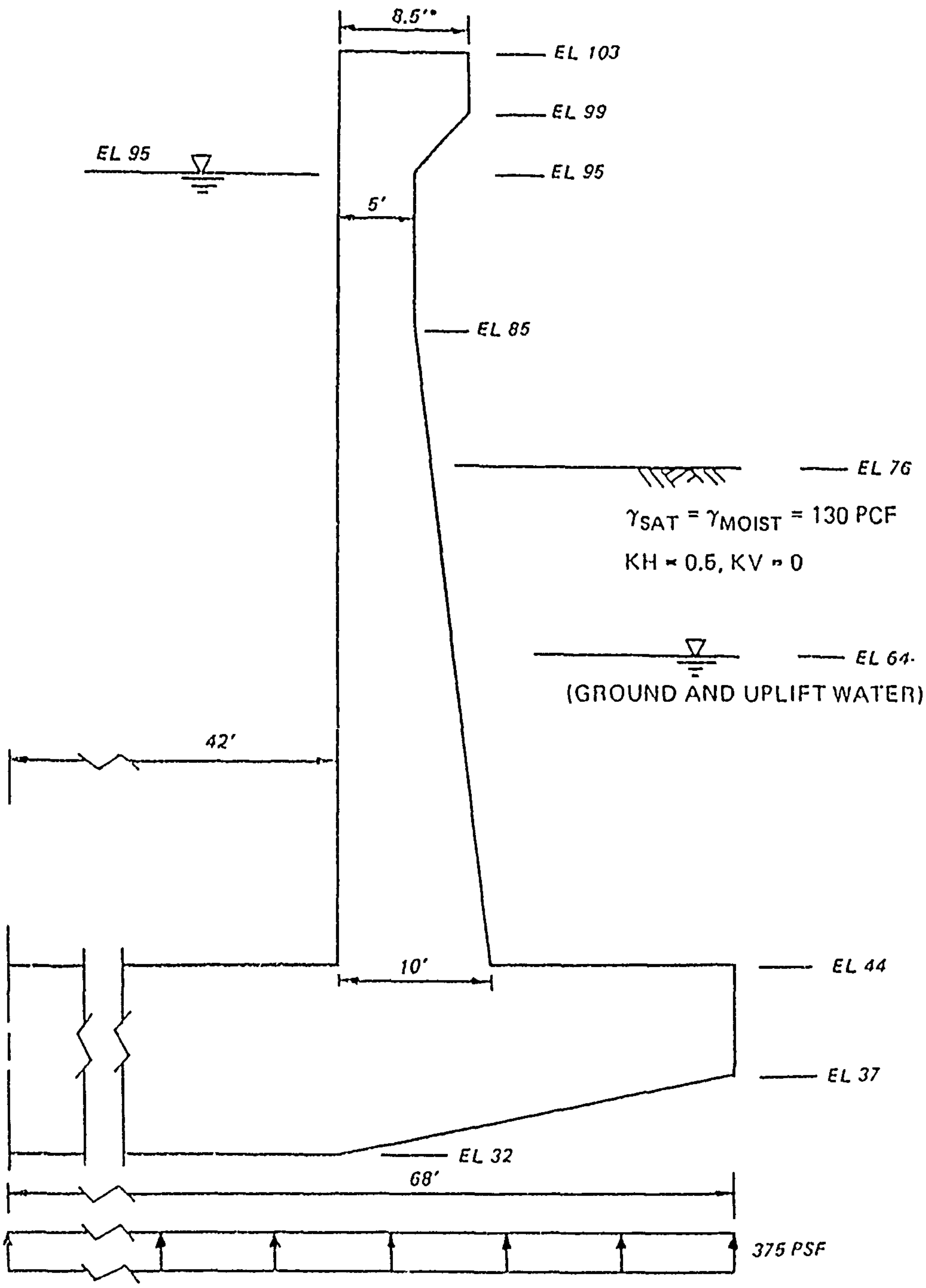


Figure 44. System for Example 1

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89                                                 TIME: 11:02:46

ARE INPUT DATA TO BE PROVIDED FROM A DATA FILE
CONTAINING DATA FOR A SEQUENCE OF PROBLEMS?
ENTER 'YES' OR 'NO'
? N

ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
ENTER 'TERMINAL' OR 'FILE'
? T
ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
ENTER 2 HEADING LINES
? EXAMPLE 1 - TYPE 1 MONOLITH
? SYMMETRIC SOIL-FOUNDED STRUCTURE
ENTER METHOD OF ANALYSIS ('EQUIL' OR 'FRAME').
? F
ENTER RIGID LINK FACTOR (0.LE.RLF.LE.ONE).
? 0.75
ENTER MEMBER FORCE FACTOR (FORFAC.GT.ONE).
? 1.0
ENTER STRUCTURE CONTROL DATA:
     <-------CONCRETE PROPERTIES------->
     MODULUS OF      POISSON'S     UNIT       THICKNESS
     ELASTICITY        RATIO      WEIGHT      OF SLICE
        (PSI)       (0<PR<0.5)    (PCF)         (FT)
? 3.0E6 0.2 150 1
ENTER STRUCTURE FLOOR DATA:
     WIDTH     ELEVATION     FILLET
      (FT)        (FT)        (FT)
? 42 44 0
ENTER RIGHTSIDE BASE DATA (1 OR 2 POINTS):
     <--------FIRST POINT-------->         <-------SECOND POINT-------->
     DISTANCE FROM       ELEVATION         DISTANCE FROM        ELEVATION
     CENTERLINE (FT)        (FT)           CENTERLINE (FT)         (FT)
? 42 32 68 37
ARE RIGHTSIDE AND LEFTSIDE BASE POINTS SYMMETRIC?
ENTER 'YES' OR 'NO'.
? Y
ENTER RIGHTSIDE STEM DATA, ONE POINT AT A TIME.
ENTER 'END' WHEN FINISHED WITH RIGHTSIDE STEM DATA.
     DIST. FROM
      STEM FACE      ELEVATION
        (FT)           (FT)
? 8.5 103
? 8.5 99
? 5 95
? 5 85
? 10 44
? 26 44
? E
ARE LEFTSIDE AND RIGHTSIDE STEM DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.
? Y
```

Figure 45. Terminal entry for example 1 (Sheet 1 of 5)

```
    IS RIGHTSIDE CULVERT PRESENT?
    ENTER 'YES' OR 'NO'.
? N
    IS  LEFTSIDE CULVERT PRESENT?
    ENTER 'YES' OR 'NO'.
? N
    IS RIGHTSIDE STEM VOID PRESENT?  ENTER 'YES' OR 'NO'.
? N
    IS  LEFTSIDE STEM VOID PRESENT?  ENTER 'YES' OR 'NO'.
? N
    IS CENTER STEM PRESENT?  ENTER 'YES' OR 'NO'.
? N
    ARE RIGHTSIDE BACKFILL DATA TO BE PROVIDED?
    ENTER 'YES' OR 'NO'
? Y
    ARE BACKFILL EFFECTS PROVIDED BY SOIL DATA OR A PRESSURE DISTRIBUTION?
    ENTER 'SOIL' OR 'PRESSURE'
? S
    ENTER NUMBER OF RIGHTSIDE SOIL LAYERS (1 TO 5).
? 1
    ENTER DATA FOR 1 RIGHTSIDE SOIL LAYERS, ONE LINE PER LAYER:
    ELEVATION AT    SOIL UNIT WEIGHTS      <----SOIL COEFFICIENTS---->
    TOP OF LAYER    SATURATED   MOIST      HORIZ PRESS    SHEAR STRESS
        (FT)          (PCF)     (PCF)      TOP  BOTTOM    TOP   BOTTOM
? 76 130 130 .5 .5 0 0
    ENTER RIGHTSIDE SURCHARGE (PCF).
? 0
    ARE LEFTSIDE AND RIGHTSIDE BACKFILL CONDITIONS SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? Y
    IS BASE REACTION PROVIDED BY SOIL OR PILES?
    ENTER 'SOIL' OR 'PILES'.
? S
    ENTER BASE REACTION DISTRIBUTION TYPE:
    'UNIFORM', 'TRAPEZOIDAL', 'RECTANGULAR', OR 'INPUT'.
? U
    ARE WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO'.
? Y
    ENTER WATER UNIT WEIGHT (PCF).
? 62.5
    ARE RIGHTSIDE EXTERNAL WATER DATA TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? Y
    ARE RIGHTSIDE EXTERNAL WATER EFFECTS TO BE PROVIDED BY ELEVATION DATA OR
    INPUT PRESSURE DATA?  ENTER 'ELEVATIONS' OR 'PRESSURES'.
? E
    ENTER RIGHTSIDE GROUND WATER ELEVATION (FT).
? 64
    ENTER RIGHTSIDE SURCHARGE WATER ELEVATION (FT) OR 'NONE'.
? N
    ARE LEFTSIDE AND RIGHTSIDE EXTERNAL WATER DATA SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? Y
    ARE UPLIFT WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO.'
? Y
    ARE UPLIFT WATER EFFECTS TO BE PROVIDED BY WATER ELEVATIONS OR BY
    A PRESSURE DIAGRAM?  ENTER 'ELEVATIONS' OR 'PRESSURES'.
? E
```

Figure 45. (Sheet 2 of 5)

```
    ENTER UPLIFT WATER ELEVATIONS (FT)
         LEFTSIDE        RIGHTSIDE
? 64 64
    ARE INTERNAL WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO'.
? Y
    ENTER WATER ELEVATION IN CHAMBER (FT).
? 95
    ARE ADDITIONAL LOAD DATA TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? Y
    ARE ADDITIONAL LOADS ON EXTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON EXTERIOR FACE OF  LEFTSIDE STEM TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON INTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON INTERIOR FACE OF  LEFTSIDE STEM TO BE ENTERED?
? N
    ARE ADDITIONAL LOADS ON TOP OF RIGHTSIDE STEM TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON TOP OF  LEFTSIDE STEM TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON  LEFTSIDE OF CHAMBER FLOOR TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? N
    ARE ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE TO BE ENTERED?
    ENTER 'YES' OR 'NO'.
? Y
    ENTER DATA FOR CONCENTRATED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
    ENTER 'END' WHEN FINISHED WITH CONCENTRATED LOADS.
         DIST. FROM     HORIZONTAL      VERTICAL
         CENTERLINE.    CONC. LOAD     CONC. LOAD
            (FT)           (PLF)          (PLF)
? E
    ENTER DATA FOR DISTRIBUTED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
    ENTER 'END' WHEN FINISHED WITH DISTRIBUTED LOADS.
         DIST. FROM     HORIZONTAL      VERTICAL
         CENTERLINE.    DIST. LOAD     DIST. LOAD
            (FT)           (PSF)          (PSF)
? 0 0 -375
? 68 0 -375
? E
    ARE LOADS ON LEFTSIDE AND RIGHTSIDE OF STRUCTURE BASE SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? Y
    ARE EARTHQUAKE ACCELERATIONS TO BE APPLIED?
    ENTER 'YES' OR 'NO'.
? N
```

Figure 45. (Sheet 3 of 5)

```
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? F
     ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CWEX1O
     DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'.
? N
     DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'.
? Y
     ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? CWEX1I
     INPUT COMPLETE.
     DO YOU WANT TO PLOT THE INPUT DATA? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CWEX1O', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F
     DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? Y

     EQUILIBRIUM ANALYSIS COMPLETE.

     DO YOU WANT TO CONTINUE WITH FRAME SOLUTION?  ENTER 'YES OR 'NO'.
? Y
     DO YOU WANT TO PLOT FRAME MODEL?
     ENTER 'YES' OR 'NO'.
? Y

     DEVELOPMENT OF FRAME MODEL COMPLETE.

     DO YOU WANT TO CONTINUE WITH FRAME SOLUTION?  ENTER 'YES' OR 'NO'.
? Y




     DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
     ENTER 'YES' OR 'NO'.
? Y

     DETAILED MEMBER FORCES ARE AVAILABLE FOR
     RIGHTSIDE MEMBERS 1 THROUGH  4
     ENTER LIST OF MEMBER NUMBERS, 'ALL', OR 'NONE'.
? A

     DETAILED MEMBER FORCES ARE AVAILABLE FOR
      LEFTSIDE MEMBERS 1 THROUGH  4
     ENTER LIST OF MEMBER NUMBERS, 'ALL', OR 'NONE'.
? N
```

Figure 45. (Sheet 4 of 5)

```
     DO YOU WANT TO PLOT BASE AXIAL, SHEAR AND MOMENT DIAGRAMS?
     ENTER 'YES' OR 'NO'.


? Y
     DO YOU WANT INDIVIDUAL MEMBER PLOTS?
     ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT TO PLOT DEFORMED STRUCTURE?
     ENTER 'YES' OR 'NO'.
? Y
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
     ENTER 'YES' OR 'NO'.
? N
     DO YOU WANT TO MAKE ANOTHER 'CWFRAM' RUN? 'YES' OR 'NO'.
? N


     ********** NORMAL TERMINATION **********
```

Figure 45. (Sheet 5 of 5)

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89                                                 TIME: 11:15:00

I.--HEADING
  EXAMPLE 1 - TYPE 1 MONOLITH
  SYMMETRIC SOIL-FOUNDED STRUCTURE


                 ****************
                 *  INPUT DATA  *
                 ****************


II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR   =          .75
     MEMBER FORCE FACTOR =         1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =      .20
     UNIT WEIGHT OF CONCRETE            =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    1.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH        =      42.00 (FT)
     FLOOR ELEVATION    =      44.00 (FT)
     FLOOR FILLET SIZE =        0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CENTERLINE      ELEVATION
         (FT)           (FT)
        42.00          32.00
        68.00          37.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE      ELEVATION
         (FT)           (FT)
         8.50         103.00
         8.50          99.00
         5.00          95.00
         5.00          85.00
        10.00          44.00
        26.00          44.00
```

a. Echoprint (Continued)

Figure 46. Input data for Example 1 (Sheet 1 of 4)

III.D.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.E.--CULVERT DATA
NONE

III.F.--VOID DATA
NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
76.00	130.0	130.0	.500	.500	0.000	0.000

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

REACTION PROVIDED BY UNIFORM SOIL PRESSURE DISTRIBUTION

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 64.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 95.00 (FT)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

a. (Continued)

Figure 46. (Sheet 2 of 4)

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

VII.C.1.--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2.--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE

CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA

DIST. FROM CENTERLINE (FT)	HORIZONTAL LOAD (PSF)	VERTICAL LOAD (PSF)
0.00	0.00	-375.00
68.00	0.00	-375.00

VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE

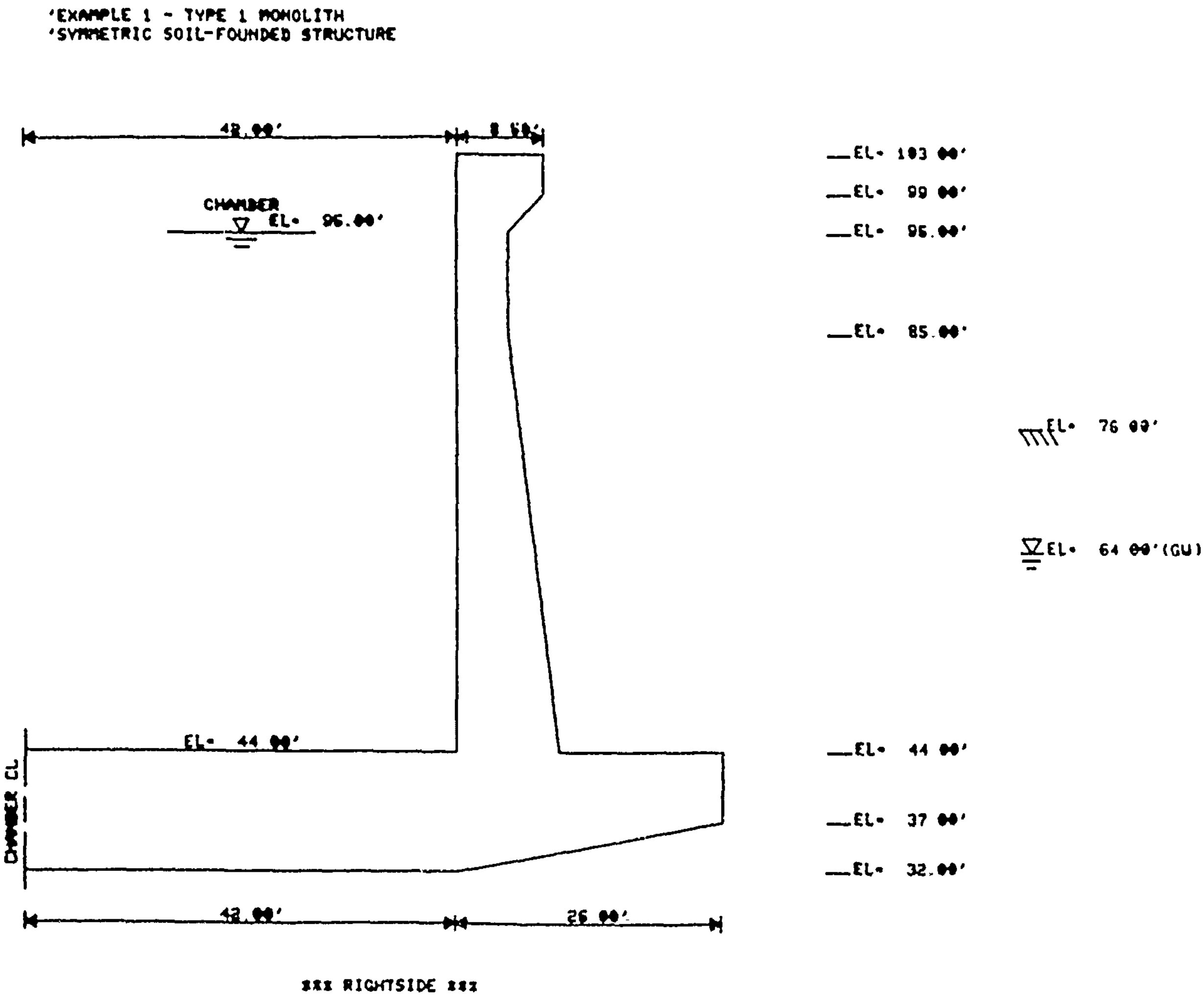
CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA
SYMMETRIC WITH RIGHTSIDE

VII.F.--EARTHQUAKE ACCELERATIONS
NONE

a. (Concluded)

Figure 46. (Sheet 3 of 4)



b. Plot of input geometry

Figure 46. (Sheet 4 of 4)

***** INPUT FILE FOR EXAMPLE 1 GENERATED BY CWFRAM *****

```
1000 'EXAMPLE 1 - TYPE 1 MONOLITH
1010 'SYMMETRIC SOIL-FOUNDED STRUCTURE
1020 METHOD  FR          .75       1.00
1030 STRUCTURE    3.00E+06         .20      150.00        1.00
1040 FLOOR            42.00      44.00        0.00
1050 BASE  BOTH                  42.00       32.00       68.00       37.00
1060 STEM  BOTH            6
1070         8.50    103.00       8.50       99.00        5.00       95.00
1080         5.00     85.00      10.00       44.00       26.00       44.00
1090 BACKFILL  BOTH      SOIL        1        0.00
1100        76.00    130.00     130.00         .50         .50        0.00        0.00
1110 REACTION SOIL UNIFORM
1120 WATER             62.5
1130 EXTERNAL  BOTH      ELEVATION           64.00
1140 UPLIFT ELEVATION            64.00       64.00
1150 INTERNAL          95.00
1160 LOADS  BOTH        BASE
1170 DIST     2         0.00       0.00     -375.00       68.00        0.00     -375.00
1180 FINISH
```

Figure 47. CWFRAM generated input file for Example 1

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89                                                 TIME: 11:16:18

I.--HEADING
  EXAMPLE 1 - TYPE 1 MONOLITH
  SYMMETRIC SOIL-FOUNDED STRUCTURE


    **************************************
    *  RESULTS OF EQUILIBRIUM ANALYSIS   *
    **************************************


 II.--EFFECTS ON STRUCTURE RIGHTSIDE


   II.A.--PRESSURES ON RIGHTSIDE SURFACE
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
     (POSITIVE SHEAR IS DOWN)
     (UNITS ARE POUNDS AND FEET)

                <----------BACKFILL PRESSURE--------->          GRND/SURCH
     ELEVATION   VERTICAL      HORIZONTAL       SHEAR          WATER PRESSURE
       103.000   0.            0.               0.               0.
        99.000   0.            0.               0.               0.
        95.000   0.            0.               0..              0.
        85.000   0.            0.               0.               0.
        76.000   0.            0.               0.               0.
        64.000   1.5600E+03    7.8000E+02       0.               0.
        44.000   2.9100E+03    1.4550E+03       0.               1.2500E+03
        44.000   2.9100E+03    1.4550E+03       0.               1.2500E+03
        37.000   3.3825E+03    1.6913E+03       0.               1.6875E+03


   II.B.--PRESSURE ON RIGHTSIDE BASE
     (POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

     DIST  FROM          SOIL REACTION          UPLIFT WATER
     CENTERLINE            PRESSURE               PRESSURE
         0.000             3.3315E+03             2.0000E+03
        42.000             3.3315E+03             2.0000E+03
        68.000             3.3315E+03             1.6875E+03
```

a. Analysis results (Continued)

Figure 48. Equilibrium analysis for Example 1 (Sheet 1 of 4)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	3.8042E+04	5.3153E+04	-2.8533E+06
GROUND/SURCH WATER	2.2781E+04	2.1524E+04	-1.2325E+06
INTERNAL WATER	-8.1281E+04	1.3388E+05	-4.1932E+06
UPLIFT WATER	9.2187E+03	-1.3194E+05	4.2947E+06
SOIL BASE REACT	0.	-2.2654E+05	7.7023E+06
BACKFILL ON BASE	8.8781E+03	0.	-8.4694E+04
ADDL BASE LOADS	0.	-2.5500E+04	8.6700E+05
CONCRETE	0.	1.7543E+05	-6.4534E+06
TOTAL THIS SIDE	-2.3612E+03	0.	-1.9530E+06

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

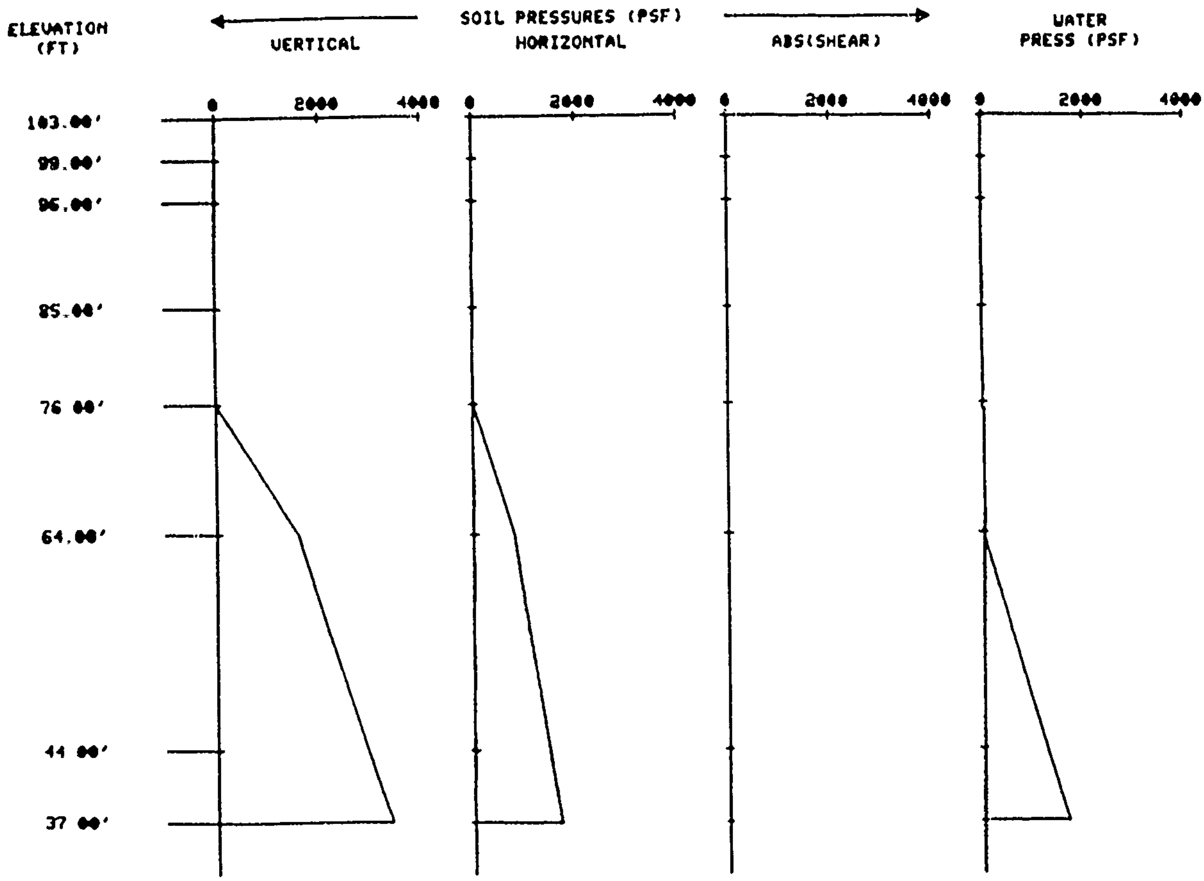
IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

V.--CONCRETE AREAS
RIGHTSIDE AREA = 1.1695E+03 (SQFT)
LEFTSIDE AREA = 1.1695E+03 (SQFT)
TOTAL AREA = 2.3390E+03 (SQFT)

a. (Concluded)

Figure 48. (Sheet 2 of 4)

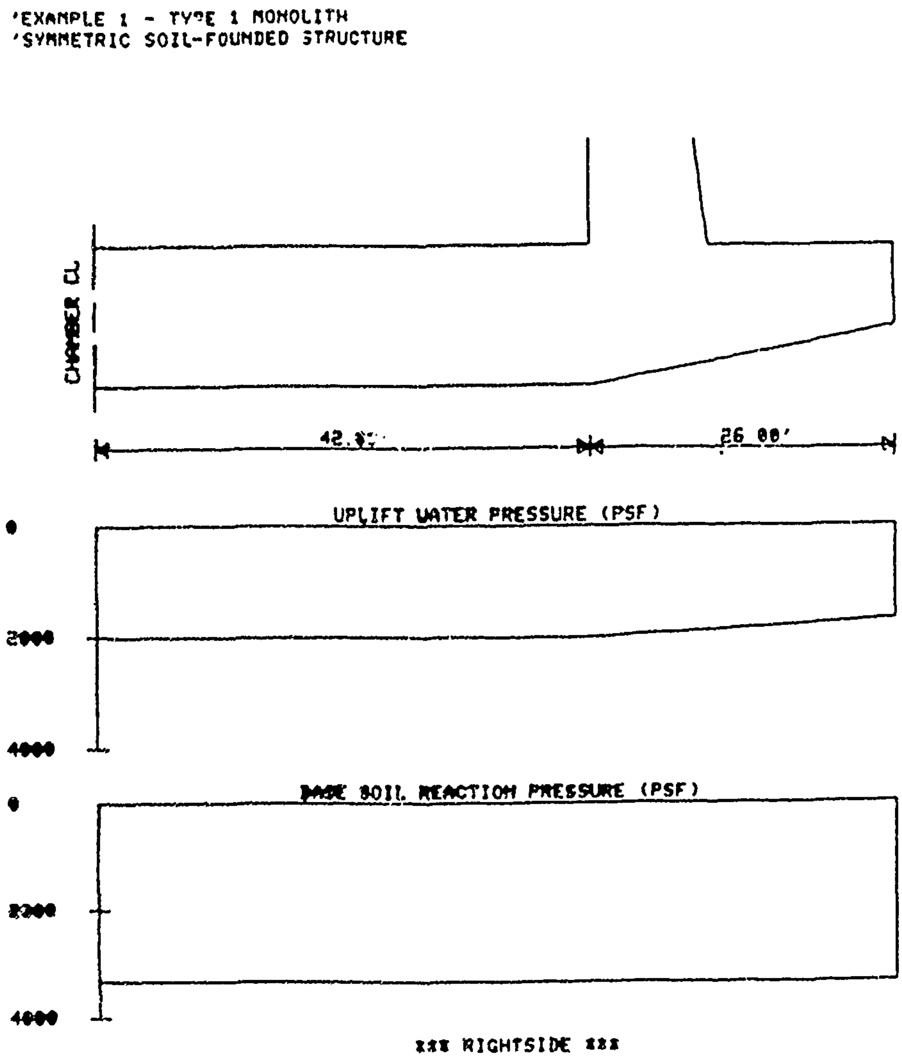
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE



*** RIGHTSIDE ***

b. Backfill and external water pressures plot

Figure 48. (Sheet 3 of 4)



c. Base soil reaction and uplift water pressure

Figure 48. (Sheet 4 of 4)

143. Pressures on the base, Section II.B. of Figure 48, consist of soil-reaction pressure developed by the program to equilibrate all vertical loads according to the prescribed "uniform" distribution as well as uplift water pressures. Locations of pressures are given by distance (right or left) from the structural centerline. When a discontinuity in pressure exists (e.g., for a prescribed "rectangular" base pressure distribution), two values are given for that location, the first being the value nearer the structural centerline. A plot of the base soil reaction and uplift water pressure is included in Figure 48.

144. Resultants of all applied loads and generated base reaction are given in Section II.C. of Figure 48. Because the structure is symmetric, mirror images of the rightside forces act on the leftside of the structure. In this case, the net resultants, Section IV. of Figure 48, are identically zero. Had the system been unsymmetric, base friction, base shear, and/or vertical stem shear would have been necessary to produce total equilibrium. For a pile-supported structure, any unbalanced total (net) resultants appearing in Figure 48, Section IV. would be resisted by piles.

145. If an equilibrium analysis had been specified, execution of the problem would cease when the equilibrium analysis had been completed. The user would then be offered the opportunity to edit existing input data or to make another run with new data.

Frame model data

146. Data for the plane frame model developed by the program are shown in Figure 49. Included are the defining coordinates of the rigid blocks associated with this type of monolith, the locations of the joints in the model, and the dimensions of the frame members. Note that the flexible lengths of the members extend into the rigid blocks due to the rigid link factors equal to 0.75. A plot of the frame model is shown in Figure 49.

Frame analysis

147. Results of the frame analysis are shown in Figure 50. Included are the displacements of the joints of the model, Section II.A., and the forces acting on the ends of the flexible length of each member parallel and perpendicular to the flexible member centerline. Pile head forces of pile allowables comparison would be contained in this tabulation for a pile-supported structure (Example 2, paragraphs 151 through 156). A plot of the axial, shear, and bending forces throughout the base is shown in Figure 50.

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89 TIME: 11:16:37

I.--HEADING
EXAMPLE 1 - TYPE 1 MONOLITH
SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* FRAME MODEL DATA *
****

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 1 MONOLITH
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

		<---------------		CORNER LOCATIONS		--------------->		
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	42.00	42.00	52.00	52.00	52.00	42.00	46.85
	ELEVATION	32.00	44.00	44.00	44.00	33.92	32.00	38.47
6	X-COORD.	42.00	42.00	50.50	50.50	47.00	47.00	45.90
	ELEVATION	95.00	103.00	103.00	99.00	95.00	95.00	99.31

II.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	38.00000
2	46.85482	38.46681
3	68.00000	40.50000
4	44.50000	85.00000
5	45.89617	99.30601

II.C.--MEMBER DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

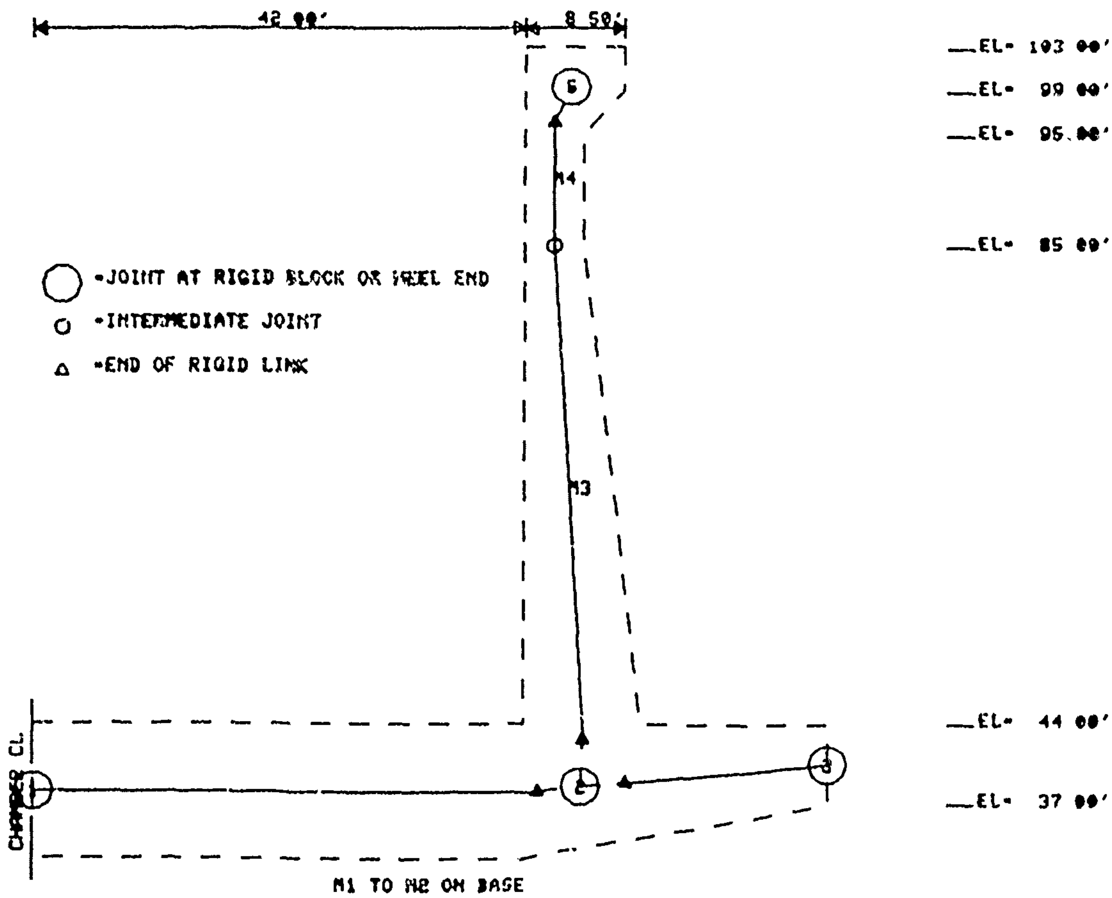
			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	38.00	43.21	38.00	12.00	12.00
2	2	3	50.71	38.84	68.00	40.50	10.08	7.00
3	2	4	47.08	42.62	44.50	85.00	10.00	5.00
4	4	5	44.50	85.00	44.50	96.08	5.00	5.00

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

a. Model data

Figure 49. Plane frame model r Example 1 (Continued)

'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE



*** RIGHTSIDE MODEL ***

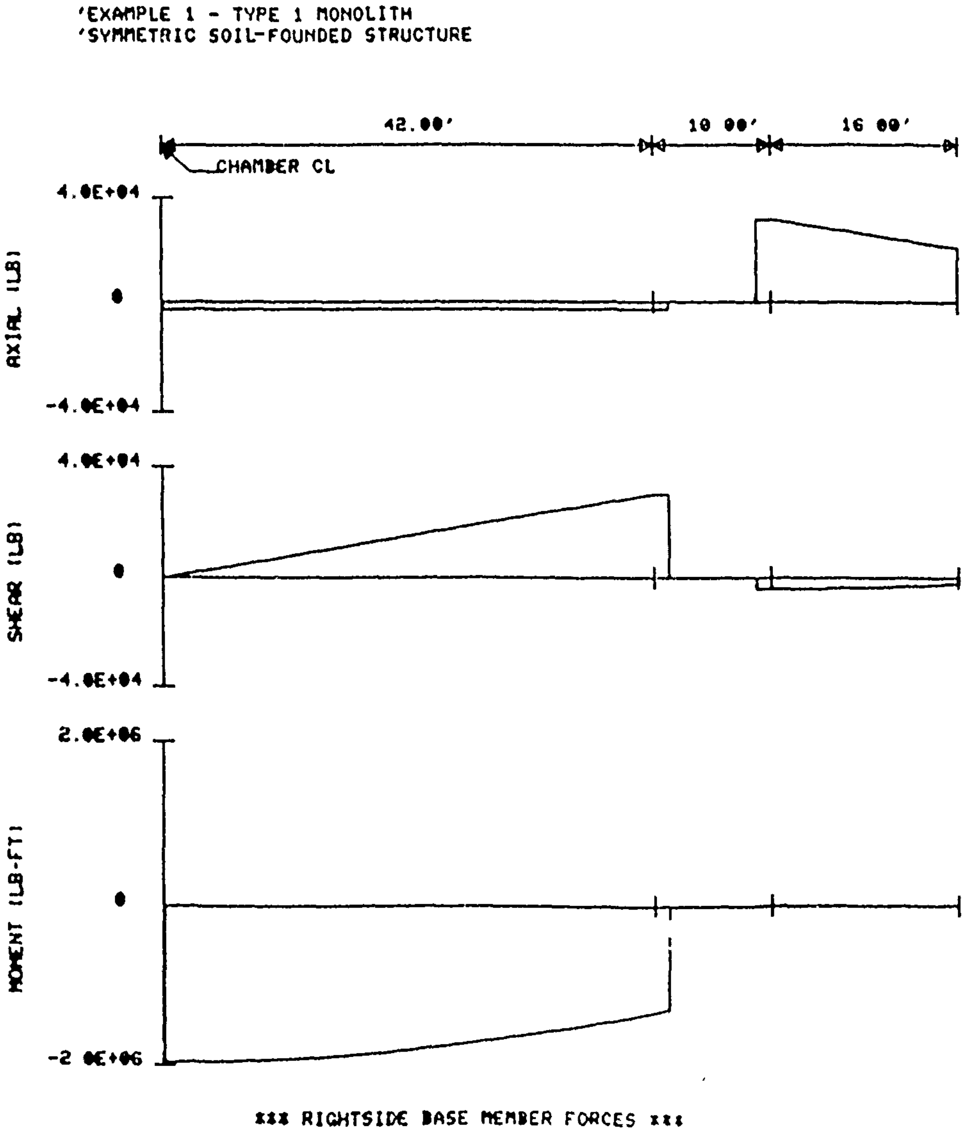
b. Frame model plot

Figure 49. (Concluded)

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89                                                  TIME: 11:16:51

I.--HEADING
  EXAMPLE 1 - TYPE 1 MONOLITH
  SYMMETRIC SOIL-FOUNDED STRUCTURE


                    ******************************
                    *  RESULTS OF FRAME ANALYSIS  *
                    ******************************

II.--STRUCTURE DISPLACEMENTS

  II.A.--RIGHTSIDE DISPLACEMENTS - TYPE  1 MONOLITH
     (POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD STRUCTURE CENTERLINE.)
     (POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
     (POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT    DISTANCE FROM   ELEVATION    <----DISPLACEMENT (FT OR RADIANS)---->
NO    CTR-LINE (FT)     (FT)       HORIZONTAL       VERTICAL       ROTATION
                          ***** BASE JOINTS *****
 1            0.00      38.00      0.               0.             0.
 2           46.85      38.47      -5.850E-04       3.263E-02      -1.211E-03
 3           68.00      40.50      -2.956E-03       5.823E-02      -1.211E-03

                          ***** STEM JOINTS *****
 4           44.50      85.00      -7.801E-02       2.879E-02      -1.899E-03
 5           45.90      99.31      -1.055E-01       3.156E-02      -1.936E-03

  II.B.-- LEFTSIDE DISPLACEMENTS - TYPE  1 MONOLITH
     SYMMETRIC WITH RIGHTSIDE

 III.--UNFACTORED FORCES AT ENDS OF MEMBERS
     (MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

   III.A.--RIGHTSIDE MEMBERS - TYPE  1 MONOLITH
     (POSITIVE AXIAL FORCE IS COMPRESSION.)
     (POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD
          STRUCTURE CENTERLINE.)
     (POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER
          OR ON SIDE OF MEMBER TOWARD STRUCTURE CENTERLINE.)

MEM   DISTANCE FROM   ELEVATION    <--------FORCES (LBS OR LB-FT)------->
NO    CTR-LINE (FT)     (FT)          AXIAL          SHEAR          MOMENT
                          ***** BASE MEMBERS *****
 1            0.00      38.00      -2.361E+03     0.              -1.967E+06
             43.21      38.00      -2.361E+03     -3.020E+04      -1.296E+06
 2           50.71      38.84       3.192E+04     -3.863E+03       8.844E+03
             68.00      40.50       2.120E+04      2.038E+03      -2.751E+03

                          ***** STEM MEMBERS *****
 3           47.08      42.62       7.330E+04      3.736E+04      -9.808E+05
             44.50      85.00       1.681E+04     -2.106E+03      -2.319E+04
 4           44.50      85.00       1.665E+04      3.125E+03      -2.319E+04
             44.50      96.08       9.150E+03     0.              -1.277E+04

   III.B.-- LEFTSIDE MEMBERS - TYPE  1 MONOLITH
     SYMMETRIC WITH RIGHTSIDE
```

a. Analysis results

Figure 50. Results of frame analysis for Example 1 (Continued)



b. Frame model plot

Figure 50. (Concluded)

Detailed member forces

148. Member internal forces are shown in Figure 51. These forces are components parallel and perpendicular to the member centerline. They are reported at the tenth points along the member, on either side of an applied concentrated load where a discontinuity in axial and/or shear would occur at the face of each rigid block to which the member is attached. A plot of the internal forces for each member is included in Figure 51.

Termination

149. Following completion of all output, the user is again offered the opportunity to edit existing data, to run the program with data, or to terminate execution. Any abnormal interruption of the program before the "normal termination" indicated may result in the loss of any generated output files.

150. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.

Example 2--Type 2 Monolith

151. The right half of the symmetric structure is shown in Figure 52. Because the rightside and leftside backfill soils are at different elevations and due to unsymmetric additional loads, the entire system is unsymmetric. An equilibrium analysis was initially performed for a 6-ft-thick slice of the soil-supported system. Example 2A is referred to in Figures 53, 54, and 55. A listing of the predefined input data file is shown in Figure 53 and an echoprint of input data is given in Figure 54. Results of the equilibrium analysis are shown in Figure 55. Note that equilibrium of the unsymmetric system was achieved by addition of friction on the base of the structure and by skewing of the nominally rectangular base reaction distribution.

152. Following the initial equilibrium analysis, the input data were edited to prescribe a frame analysis and to change from soil to pile supports as shown in Figure 56. Example 2B of the type 2 monolith is referred to in Figures 56, 57, 58, and 59. A listing of the input file for the new system (generated by the program) is shown in Figure 57. An echoprint of the existing input data is given in Figure 58. Plots of the rightside geometry are also included in Figure 58.

153. Results of the equilibrium analysis are shown in Figure 59. The nonzero net resultants, due to unsymmetric loading, are resisted by the piles.

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 06/28/89 TIME: 11:17:18

I.--HEADING
EXAMPLE 1 - TYPE 1 MONOLITH
SYMMETRIC SOIL-FOUNDED STRUCTURE

II.--MEMBER INTERNAL FORCES
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION UP OR TOWARD THE CENTERLINE.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE TOP OF THE MEMBER OR ON THE SIDE OF THE MEMBER TOWARD THE CENTERLINE.)

II.A.1.--UNFACTORED RIGHTSIDE MEMBER FORCES - TYPE 1 MONOLITH

***** RIGHTSIDE MEMBER 1

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
0.00	38.00	-2.361E+03	0.	-1.967E+06
4.32	38.00	-2.361E+03	3.107E+03	-1.960E+06
8.64	38.00	-2.361E+03	6.214E+03	-1.940E+06
12.96	38.00	-2.361E+03	9.321E+03	-1.907E+06
17.29	38.00	-2.361E+03	1.243E+04	-1.860E+06
21.61	38.00	-2.361E+03	1.553E+04	-1.799E+06
25.93	38.00	-2.361E+03	1.864E+04	-1.725E+06
30.25	38.00	-2.361E+03	2.175E+04	-1.638E+06
34.57	38.00	-2.361E+03	2.486E+04	-1.537E+06
38.89	38.00	-2.361E+03	2.796E+04	-1.423E+06
42.00	38.00	-2.361E+03	3.020E+04	-1.333E+06
43.21	38.00	-2.361E+03	3.020E+04	-1.296E+06

***** RIGHTSIDE MEMBER 2

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
50.71	38.84	3.192E+04	-3.863E+03	8.844E+03
52.00	38.96	3.192E+04	-3.863E+03	3.853E+03
52.44	39.00	3.161E+04	-3.869E+03	3.666E+03
54.17	39.17	3.039E+04	-3.861E+03	2.782E+03
55.90	39.34	2.919E+04	-3.805E+03	1.717E+03
57.63	39.50	2.800E+04	-3.700E+03	5.589E+02
59.36	39.67	2.683E+04	-3.545E+03	-6.032E+02
61.09	39.84	2.567E+04	-3.342E+03	-1.681E+03
62.81	40.00	2.453E+04	-3.090E+03	-2.586E+03
64.54	40.17	2.340E+04	-2.788E+03	-3.230E+03
66.27	40.33	2.229E+04	-2.438E+03	-3.524E+03
68.00	40.50	2.120E+04	-2.038E+03	-3.381E+03

a. Internal forces (Continued)

Figure 51. Detailed member forces for Example 1 (Sheet 1 of 6)

***** RIGHTSIDE MEMBER 3

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
47.08	42.62	7.330E+04	3.736E+04	-9.868E+05
47.00	44.00	7.330E+04	3.736E+04	-9.351E+05
46.83	46.86	6.763E+04	3.619E+04	-8.231E+05
46.57	51.09	5.969E+04	3.391E+04	-6.657E+05
46.31	55.33	5.232E+04	3.099E+04	-5.209E+05
46.05	59.57	4.553E+04	2.743E+04	-3.915E+05
45.79	63.81	3.932E+04	2.322E+04	-2.800E+05
45.53	68.05	3.369E+04	1.863E+04	-1.887E+05
45.28	72.29	2.868E+04	1.396E+04	-1.181E+05
45.02	76.52	2.427E+04	9.208E+03	-6.861E+04
44.76	80.76	2.034E+04	5.107E+03	-3.861E+04
44.50	85.00	1.681E+04	2.106E+03	-2.368E+04

***** RIGHTSIDE MEMBER 4

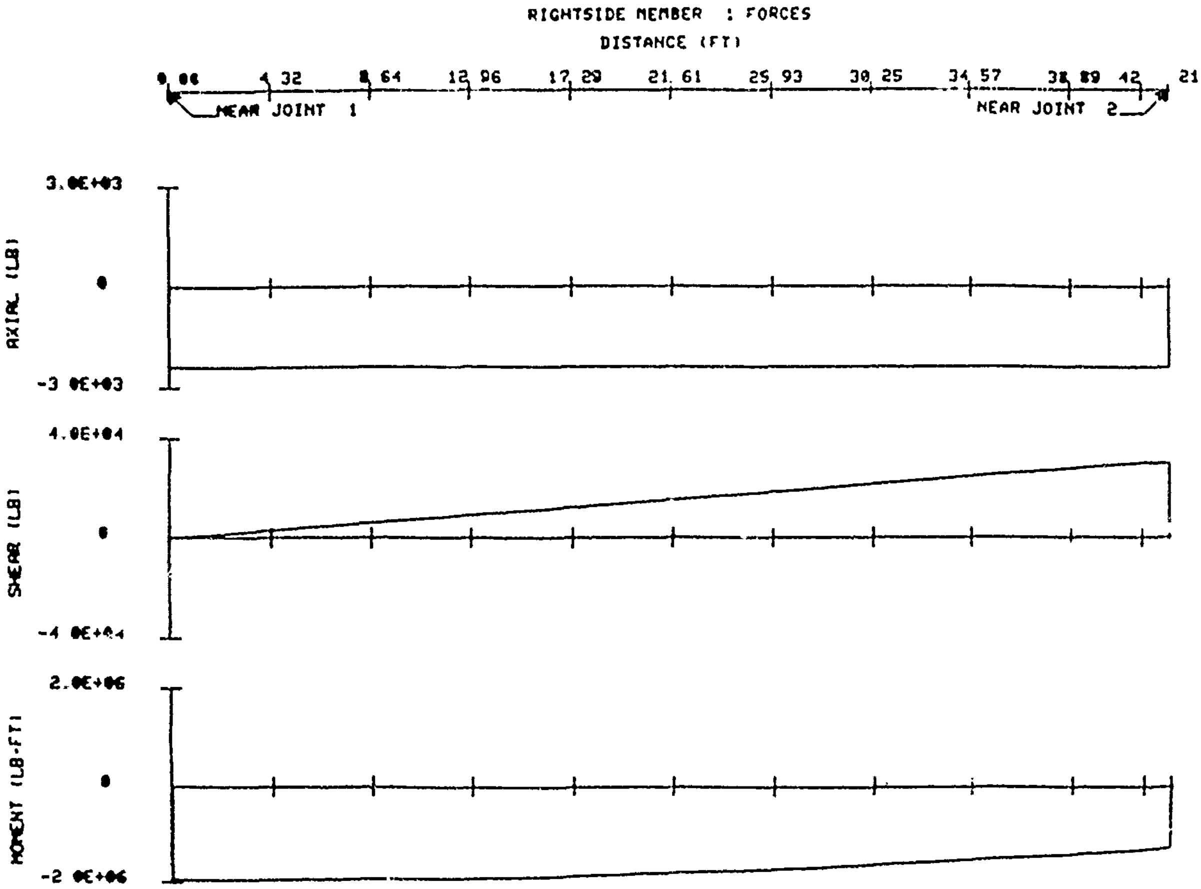
DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
44.50	85.00	1.665E+04	3.125E+03	-2.319E+04
44.50	86.11	1.582E+04	2.471E+03	-2.010E+04
44.50	87.22	1.499E+04	1.894E+03	-1.769E+04
44.50	88.32	1.416E+04	1.393E+03	-1.588E+04
44.50	89.43	1.333E+04	9.693E+02	-1.457E+04
44.50	90.54	1.250E+04	6.221E+02	-1.370E+04
44.50	91.65	1.167E+04	3.516E+02	-1.317E+04
44.50	92.75	1.083E+04	1.577E+02	-1.289E+04
44.50	93.86	1.000E+04	4.053E+01	-1.279E+04
44.50	94.97	9.173E+03	3.032E-02	-1.278E+04
44.50	95.00	9.150E+03	1.180E-08	-1.277E+04
44.50	96.08	9.150E+03	1.180E-08	-1.277E+04

II.B.-- LEFTSIDE MEMBERS
SYMMETRIC WITH RIGHTSIDE MEMBERS

a. (Concluded)

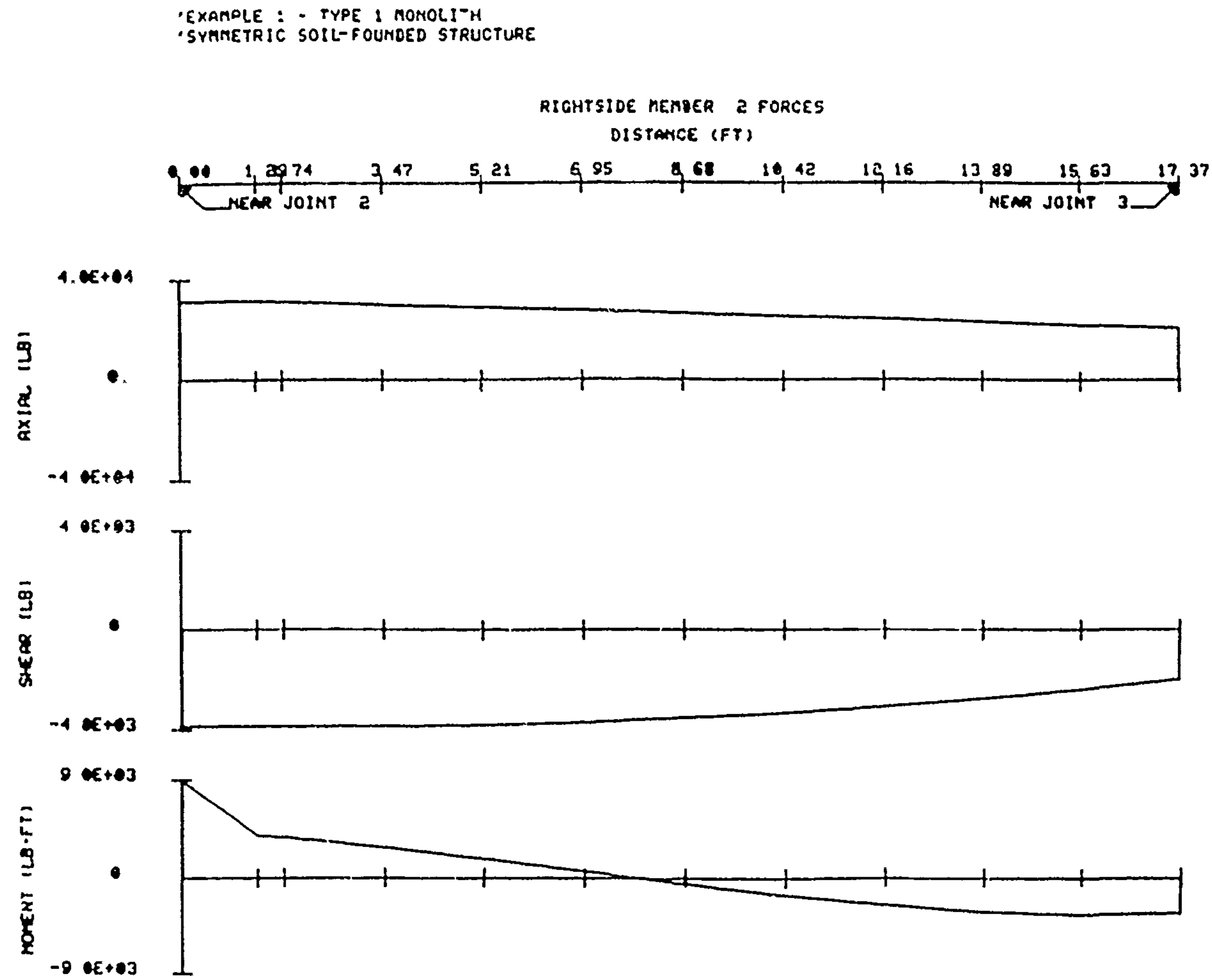
Figure 51. (Sheet 2 of 6)

'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE



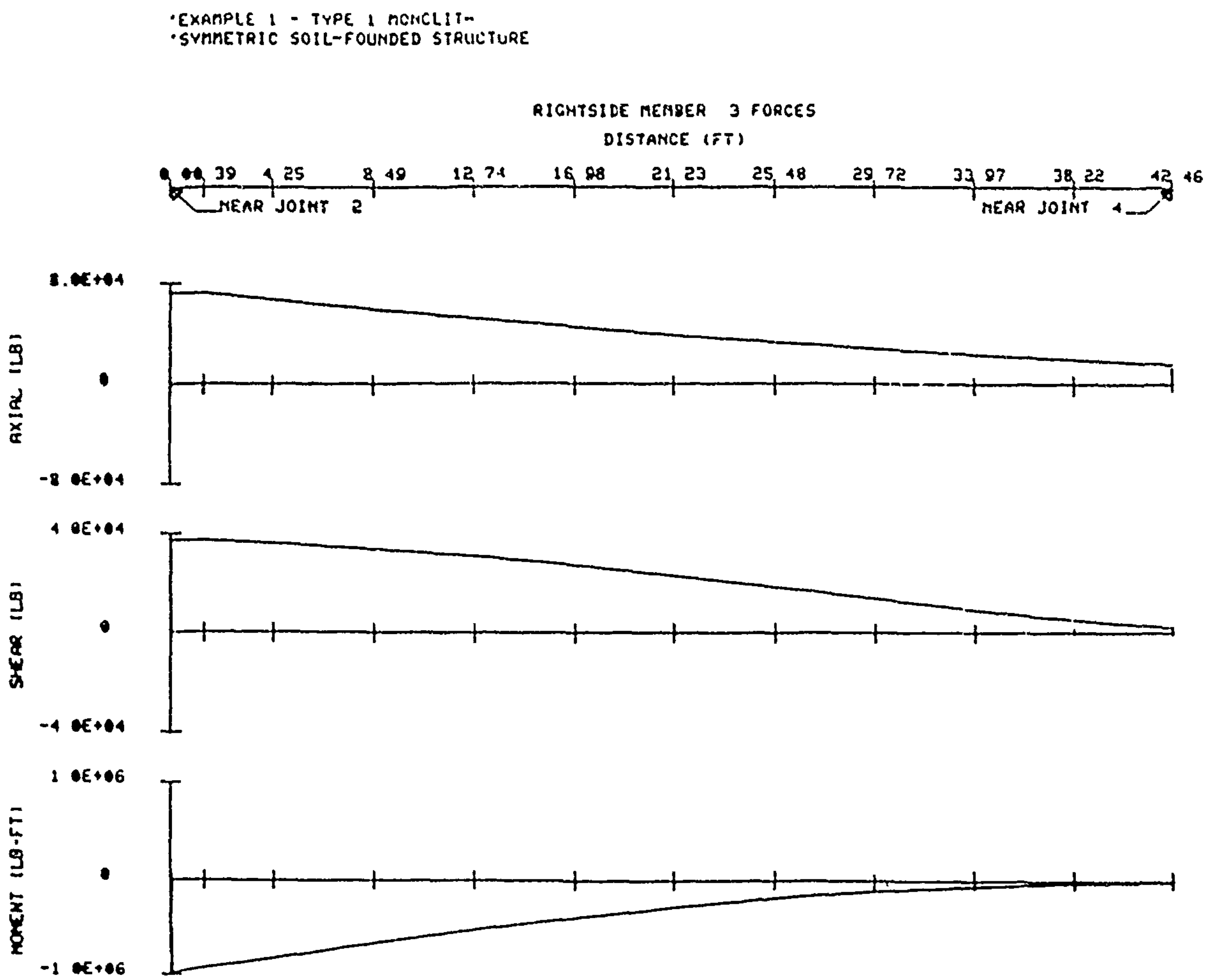
b. Plot for member 1 forces

Figure 51. (Sheet 3 of 6)



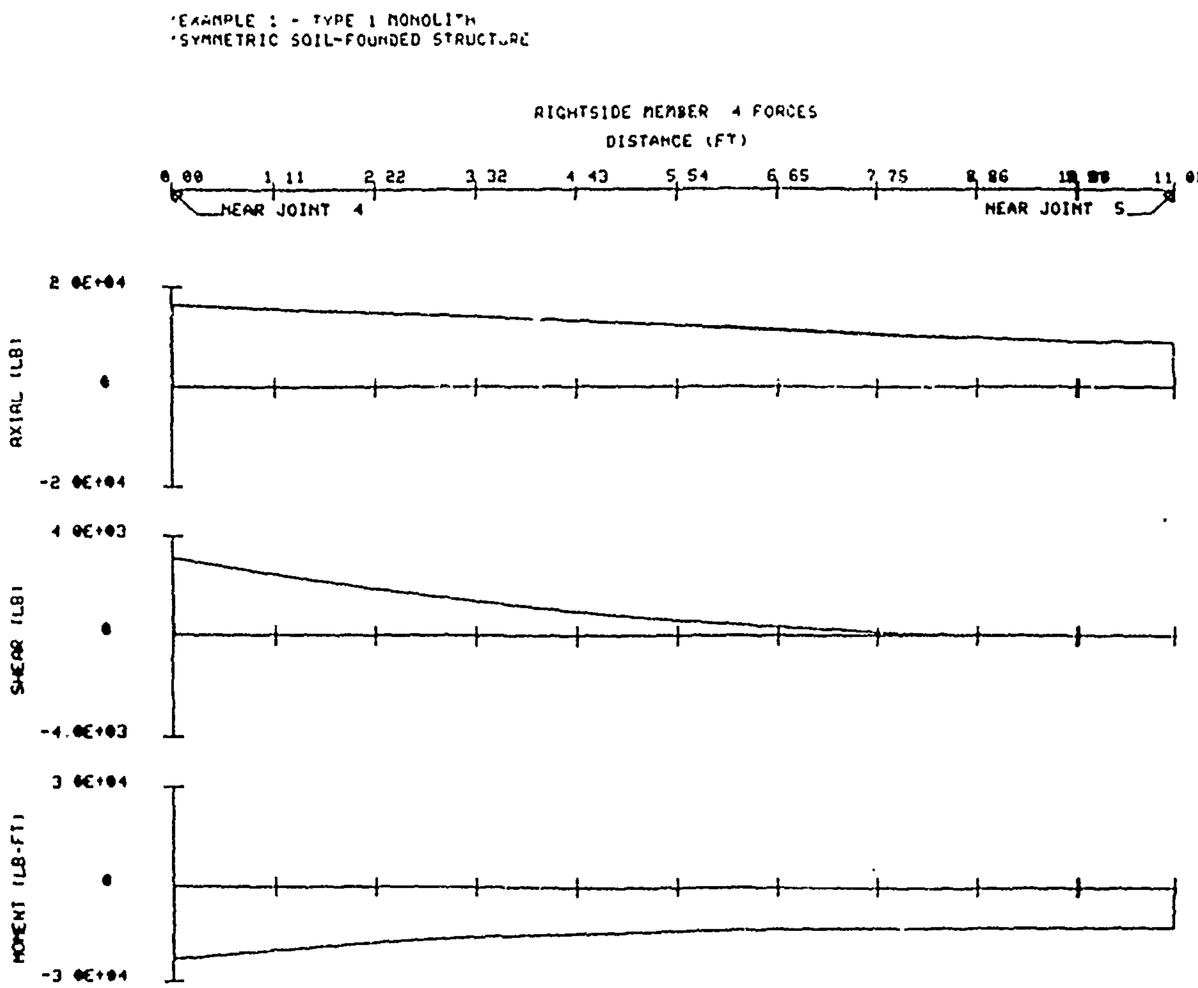
c. Plot for member 2 forces

Figure 51. (Sheet 4 of 6)



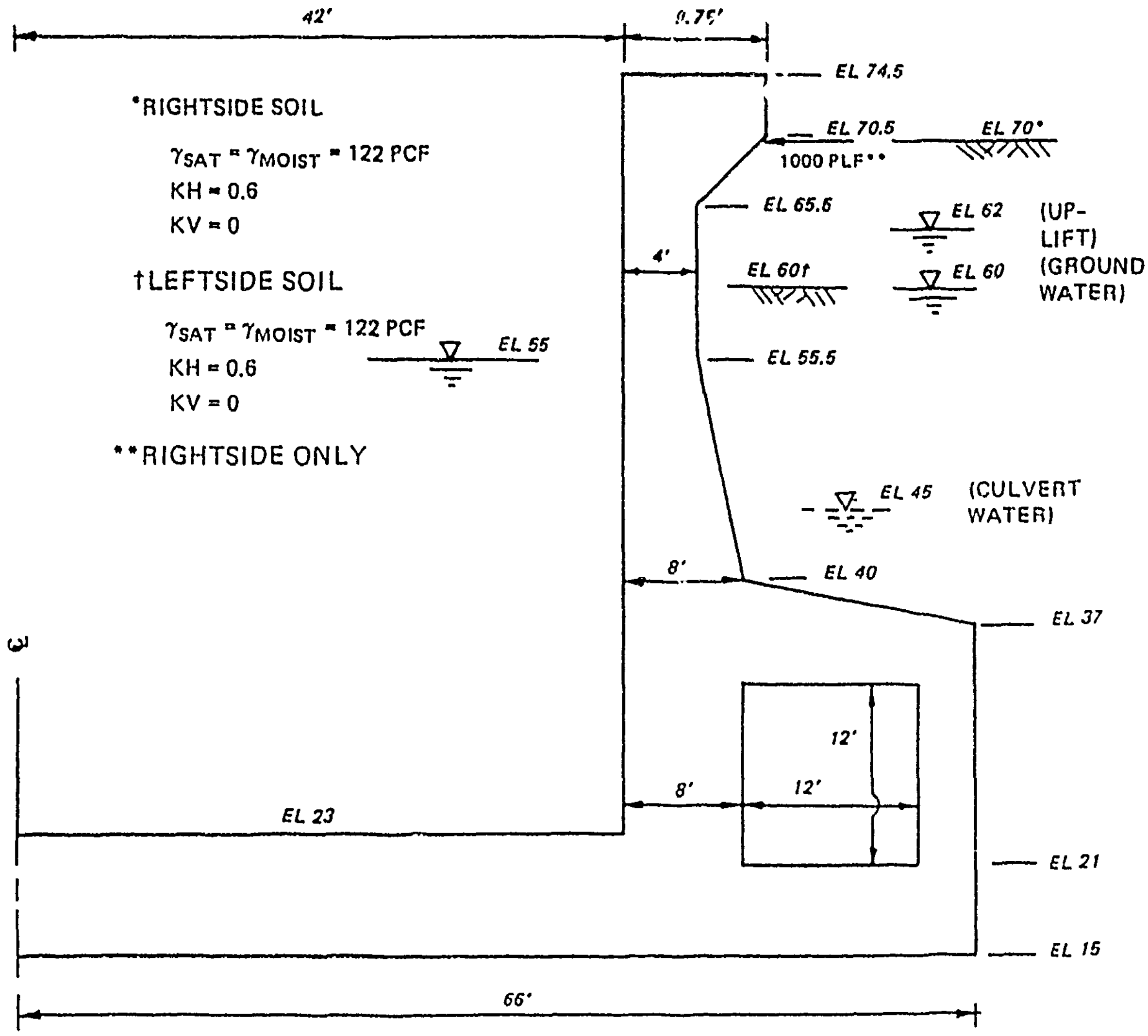
d. Plot for member 3 forces

Figure 51. (Sheet 5 of 6)

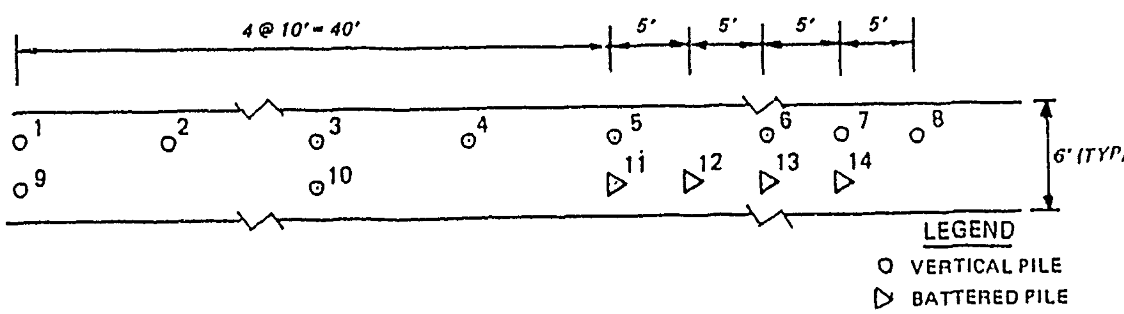


e. Plot for member 4 forces

Figure 51. (Sheet 6 of 6)



a. Structure, soil, and water data



b. Pile layout

Figure 52. System for Example 2

```
     PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
     DATE: 07/06/89                                                   TIME: 11:16:33

     ARE INPUT DATA TO BE PROVIDED FROM A DATA FILE
     CONTAINING DATA FOR A SEQUENCE OF PROBLEMS?
     ENTER 'YES' OR 'NO'.
? N

     ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
     ENTER 'TERMINAL' OR 'FILE'.
? F
     ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CWEX2I
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? F
     ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CWEX2A
     DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'.
? N
     INPUT COMPLETE.
     DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.
? N
     DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CWEX2A', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F


     RESULTANT OF ALL HORIZONTAL LOADS IS    -2.25600E+05 (LBS).
     DO YOU WANT TO TERMINATE THIS PROBLEM, EQUILIBRATE HORIZONTAL LOADS BY
     FRICTION ON BASE OR EQUILIBRATE HORIZONTAL LOADS BY SHEAR IN BASE?
     ENTER 'TERMINATE', 'FRICTION', OR 'SHEAR'.
? F
     DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? N

1000 'EXAMPLE 2A - TYPE 2 MONOLITH
1010 'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITION LOADS
1020 'SOIL-FOUNDED STRUCTURE
1030 METHOD  EQ
1040 STRUCTURE   3.00E+06        .20     150.00       6.00
1050 FLOOR            42.00    23.00       0.00
1060 BASE  BOTH                66.00      15.00
1070 STEM  BOTH           8
1080        9.75     74.50      9.75      70.50       4.00      65.50
1090        4.00     55.50      8.00      40.00      24.00      37.00
1100       24.00     21.00     24.00      21.00
1110 CULVERT  BOTH              8.00      12.00      21.00      12.00      0.00
1120 BACKFILL RIGHTSIDE SOIL       1       0.00
1130       70.00    122.00    122.00        .60        .60       0.00      0.00
1140 BACKFILL  LEFTSIDE SOIL       1       0.00
1150       60.00    122.00    122.00        .60        .60       0.00      0.00
1160 REACTION SOIL RECTANGULAR              .50
1170 WATER            62.5
1180 EXTERNAL  BOTH      ELEVATION        60.00
1190 UPLIFT ELEVATION          62.00      62.00
1200 INTERNAL         55.00    45.00      45.00
1210 LOADS RIGHTSIDE STEM EXTERIOR
1220 CONC    1        70.00  1000.00       0.00
1230 FINISH
```

Figure 53. Program execution and input file for Example 2A

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89                                                  TIME: 11:17:35

I.--HEADING
  'EXAMPLE 2A - TYPE 2 MONOLITH
  'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITION LOADS
  'SOIL-FOUNDED STRUCTURE

               ****************
               *  INPUT DATA  *
               ****************


II.--EQUILIBRIUM ANALYSIS ONLY

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
    MODULUS OF ELASTICITY OF CONCRETE   =    3.000E+06 (PSI)
    POISSON'S RATIO FOR CONCRETE        =     .20
    UNIT WEIGHT OF CONCRETE             =   150.0    (PCF)
    THICKNESS OF TWO-DIMENSIONAL SLICE  =    6.00    (FT)

  III.B.--FLOOR DATA
    FLOOR WIDTH       =       42.00 (FT)
    FLOOR ELEVATION   =       23.00 (FT)
    FLOOR FILLET SIZE =        0.00 (FT)

  III.C.--BASE DATA

   III.C.1.--RIGHTSIDE
    DISTANCE FROM
     CENTERLINE       ELEVATION
         (FT)            (FT)
        66.00           15.00

   III.C.2.--LEFTSIDE
    SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

   III.D.1.--RIGHTSIDE
    DISTANCE FROM
      STEM FACE       ELEVATION
         (FT)            (FT)
          9.75          74.50
          9.75          70.50
          4.00          65.50
          4.00          55.50
          8.00          40.00
         24.00          37.00
         24.00          21.00
         24.00          21.00

   III.D.2.--LEFTSIDE
    SYMMETRIC WITH RIGHTSIDE.
```

Figure 54. Echoprint of input data for Example 2A (Sheet 1 of 3)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00 (FT)
CULVERT WIDTH	=	12.00 (FT)
ELEVATION AT CULVERT FLOOR	=	21.00 (FT)
CULVERT HEIGHT	=	12.00 (FT)
CULVERT FILLET SIZE	=	0.00 (FT)

III.E.2.--LEFTSIDE

SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA

NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
70.00	122.0	122.0	.600	.600	0.000	0.000

IV.B.-- LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
60.00	122.0	122.0	.600	.600	0.000	0.000

V.--BASE REACTION DATA

REACTION PROVIDED BY RECTANGULAR SOIL PRESSURE DISTRIBUTION

FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE = .50

VI.--WATER DATA

WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA

GROUND WATER ELEVATION = 60.00 (FT)

SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA

SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA

RIGHTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

LEFTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

VI.C.--INTERNAL WATER DATA

WATER ELEVATION IN CHAMBER	=	55.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT	=	45.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT	=	45.00 (FT)

Figure 54. (Sheet 2 of 3)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

CONCENTRATED LOAD DATA

ELEVATION AT LOAD (FT)	HORIZONTAL LOAD (PLF)	VERTICAL LOAD (PLF)
70.00	1000.00	0.00

DISTRIBUTED LOAD DATA
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

VII.C.1.--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2.--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
NONE

VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE
NONE

VII.F.--EARTHQUAKE ACCELERATIONS
NONE

Figure 54. (Sheet 3 of 3)

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89                                                TIME: 11:18:32

I.--HEADING
  'EXAMPLE 2A - TYPE 2 MONOLITH
  'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITION LOADS
  'SOIL-FOUNDED STRUCTURE


     ************************************
     *  RESULTS OF EQUILIBRIUM ANALYSIS  *
     ************************************


II.--EFFECTS ON STRUCTURE RIGHTSIDE

   II.A.--PRESSURES ON RIGHTSIDE SURFACE
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
     (POSITIVE SHEAR IS DOWN)
     (UNITS ARE POUNDS AND FEET)
```

	<---------BACKFILL PRESSURE	---------	--------->	GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
70.000	0.	0.	0.	0.
65.500	5.4900E+02	3.2940E+02	0.	0.
60.000	1.2200E+03	7.3200E+02	0.	0.
55.500	1.4878E+03	8.9265E+02	0.	2.8125E+02
55.000	1.5175E+03	9.1050E+02	0.	3.1250E+02
40.000	2.4100E+03	1.4460E+03	0.	1.2500E+03
37.000	2.5885E+03	1.5531E+03	0.	1.4375E+03
33.000	2.8265E+03	1.5959E+03	0.	1.6875E+03
23.000	3.4215E+03	2.0529E+03	0.	2.3125E+03
21.000	3.5405E+03	2.1243E+03	0.	2.4375E+03
15.000	3.8975E+03	2.3385E+03	0.	2.8125E+03

```
   II.B.--PRESSURE ON RIGHTSIDE BASE
     (POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)
```

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	7.9331E+02	2.9375E+03
42.000-	8.6465E+02	2.9375E+03
42.000+	3.0463E+03	2.9375E+03
50.000	3.0598E+03	2.9375E+03
62.000	3.0802E+03	2.9375E+03
66.000	3.0870E+03	2.9375E+03

Figure 55. Results of equilibrium analysis for Example 2A (Sheet 1 of 3)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	4.3648E+05	2.7818E+05	-1.0515E+07
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
SOIL BASE REACT	-1.1280E+05	-6.5050E+05	2.9210E+07
ADDL EXT STEM LOADS	6.0000E+03	0.	2.8200E+05
CONCRETE	0.	8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	5.1737E+05	4.6741E+04	6.1133E+05

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
65.500	0.	0.	0.	0.
60.000	0.	0.	0.	0.
55.500	2.6775E+02	1.6065E-02	0.	2.8125E+02
55.000	2.9750E+02	1.7850E+02	0.	3.1250E+02
40.000	1.1900E+03	7.1400E+02	0.	1.2500E+03
37.000	1.3685E+03	8.2110E+02	0.	1.4375E+03
33.000	1.6065E+03	9.6390E-02	0.	1.6875E+03
23.000	2.2015E+03	1.3209E+03	0.	2.3125E+03
21.000	2.3205E+03	1.3923E+03	0.	2.4375E-03
15.000	2.6775E+03	1.6065E+03	0.	2.8125E+03

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	7.9331E+02	2.9375E+03
42.000-	7.2197E+02	2.9375E+03
42.000+	2.9036E+03	2.9375E+03
50.000	2.8900E+03	2.9375E+03
62.000	2.8696E+03	2.9375E+03
66.000	2.8628E+03	2.9375E+03

Figure 55. (Sheet 2 of 3)

III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE

(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	2.1688E+05	1.4030E+05	-6.4746E+06
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
SOIL BASE REACT	1.1280E+05	-6.0610E+05	2.5452E+07
CONCRETE	0.	8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	5.1737E+05	-4.6741E+04	6.1133E+05

IV.--NET RESULTANTS OF ALL LOADS

(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
(UNITS ARE POUNDS AND FEET)

TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

NOTE: HORIZONTAL EQUILIBRIUM PROVIDED BY FRICTION ON BASE.

V.--CONCRETE AREAS

RIGHTSIDE AREA = 9.7438E+02 (SQFT)
LEFTSIDE AREA = 9.7438E+02 (SQFT)
TOTAL AREA = 1.9488E+03 (SQFT)

Figure 55. (Sheet 3 of 3)

```
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
     ENTER 'YES' OR 'NO'.
? Y


     MAJOR DATA SECTIONS:
        1....HEADING
        2....METHOD OF ANALYSIS
        3....STRUCTURE DATA
        4....BACKFILL DATA
        5....BASE REACTION DATA
        6....WATER DATA
        7....ADDITIONAL LOAD DATA

     TO DELETE AN ENTIRE SECTION ENTER 'DELETE' BEFORE SECTION NUMBER.

     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 1
     ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
     ENTER 2 HEADING LINES.
? EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
? WITH PILE SUPPORT

     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 2
     ENTER METHOD OF ANALYSIS ('EQUIL' OR 'FRAME').
? F
     ENTER RIGID LINK FACTOR (0.LE.RLF.LE.ONE).
? 1
     ENTER MEMBER FORCE FACTOR (FORFAC.GT.ONE).
? 1

     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 5
     CURRENT BASE REACTION IS PROVIDED BY SOIL.
     DO YOU WANT TO CHANGE TO PILE REACTION?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE LAYOUT DATA, ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE LAYOUT DATA.
          <-------START------>       STOP     <---STEP IN-->
          PILE      DIST. FROM       PILE     PILE     DIST.
           NO.      CENTERLINE.       NO.      NO.     (FT)
                       (FT)
? 1 0
? 2 10 5 1 10
? 6 50 8 1 5
? 9 0
? 10 20
? 11 40 14 1 5
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE LAYOUT DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
```

Figure 56. Data editing for Example 2B (Sheet 1 of 4)

```
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE/SOIL PROPERTIES TO BE PROVIDED?
? Y
     ARE RIGHTSIDE PILE/SOIL PROPERTIES TO BE ENTERED?
? Y
     ENTER RIGHTSIDE PILE/SOIL PROPERTIES,  ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE/SOIL DATA.
          <---------------PILE PROPERTIES--------------->
  START   MOD.   SECT     MOM             AXIAL   HEAD   <-SOIL-> STOP  PILE
   PILE   ELAST  AREA   INERTIA  LENGTH   STIFF  FIXITY  <COEFFS> PILE   NO.
   NO.    (PSI) (SQIN)  (IN**4)   (FT)    COEFF   COEFF  SS1  SS2  NO.  STEP
? 1 2.9E7 21.4 729 45 1.3 0 0 10 14 1
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE/SOIL PROPERTIES DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE HEAD STIFFNESS MATRICES TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE BATTER DATA TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? Y
     ARE RIGHTSIDE BATTER DATA TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE BATTER DATA, ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE BATTER DATA.
          START                         STOP     PILE
          PILE        BATTER            PILE     NO.
           NO.        (FT/FT)            NO.     STEP
? 11 3 14 1
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE BATTER DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE ALLOWABLE DATA TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? Y
     ARE RIGHTSIDE PILE ALLOWABLE DATA TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
```

Figure 56. (Sheet 2 of 4)

```
    ENTER RIGHTSIDE PILE ALLOWABLE DATA, ONE LINE AT A TIME.
    ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE ALLOWABLE DATA.
        <ALLOWABLE AXIAL FORCE>
 START   COMP  TENS    COMP  TENS   ALLOW   MOM   MAX    OVER STRESS   STOP  PILE
 PILE    ONLY  ONLY    WITH  WITH    BEND   MAG   MOM      FACTORS     PILE   NO.
  NO.                   BM    BM     MOM   FACT   FACT   COMP    TENS   NO.  STEP
         (K)   (K)     (K)   (K)   (K-F)          (IN)
? 1 215 88 364 364 196 1 56.6 1.33 1.33 14 1
? E
    ARE LEFTSIDE AND RIGHTSIDE PILE ALLOWABLE DATA SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? Y
    ARE ALL PILE DATA SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? Y

    ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? F
    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
    TO A FILE, TO BOTH OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? F
    ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CWEX2B
    DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'.
? N
    DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'.
? Y
    ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? CWX2BI
    INPUT COMPLETE.
    DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CWEX2B', OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F
    DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? N

    EQUILIBRIUM ANALYSIS COMPLETE.

    DO YOU WANT TO CONTINUE WITH FRAME SOLUTION?  ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT TO PLOT FRAME MODEL?
    ENTER 'YES' OR 'NO'.
? Y

    DEVELOPMENT OF FRAME MODEL COMPLETE.

    DO YOU WANT TO CONTINUE WITH FRAME SOLUTION?  ENTER 'YES' OR 'NO'.
? Y
```

Figure 56. (Sheet 3 of 4)

```
     DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
     ENTER 'YES' OR 'NO'.
? N



     DO YOU WANT TO PLOT BASE AXIAL, SHEAR AND MOMENT DIAGRAMS?
     ENTER 'YES' OR 'NO'.
? N



     DO YOU WANT TO PLOT DEFORMED STRUCTURE?
     ENTER 'YES' OR 'NO'.
? N
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
     ENTER 'YES' OR 'NO'.
? N
     DO YOU WANT TO MAKE ANOTHER 'CWFRAM' RUN? ENTER 'YES' OR 'NO'.
? N



     ********** NORMAL TERMINATION **********
```

Figure 56. (Sheet 4 of 4)

***** INPUT FILE FOR EXAMPLE 2B GENERATED BY CWFRAM *****

```
1000  'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
1010  'WITH PILE SUPPORT
1020 METHOD  FR       1.00       1.00
1030 STRUCTURE   3.00E+06        .20     150.00       6.00
1040 FLOOR            42.00      23.00       0.00
1050 BASE  BOTH                  66.00      15.00
1060 STEM  BOTH           8
1070       9.75      74.50       9.75      70.50       4.00      65.50
1080       4.00      55.50       8.00      40.00      24.00      37.00
1090      24.00      21.00      24.00      21.00
1100 CULVERT  BOTH                8.00      12.00      21.00      12.00      0.00
1110 BACKFILL RIGHTSIDE SOIL       1        0.00
1120      70.00     122.00     122.00        .60        .60       0.00      0.00
1130 BACKFILL  LEFTSIDE SOIL       1        0.00
1140      60.00     122.00     122.00        .60        .60       0.00      0.00
1150 REACTION PILES
1160 PILES  BOTH
1170 LAYOUT        1           0.00     1     1      0.00
1180 LAYOUT        2          10.00     5     1     10.00
1190 LAYOUT        6          50.00     8     1      5.00
1200 LAYOUT        9           0.00     9     1      0.00
1210 LAYOUT       10          20.00    10     1      0.00
1220 LAYOUT       11          40.00    14     1      5.00
1230 PROPS     1  2.90E+07   21.4   729.0   45.0     1.3 0.00    0.00   10.00 14   1
1240 BATTER       11           3.00    14     1
1250 ALLOW     1  215.   38.  364.  364.  196.   1.00  56.60   1.33   1.33 14   1
1260 WATER            62.5
1270 EXTERNAL  BOTH      ELEVATION       60.00
1280 UPLIFT ELEVATION          62.00      62.00
1290 INTERNAL         55.00    45.00      45.00
1300 LOADS RIGHTSIDE STEM EXTERIOR
1310 CONC     1       70.00   1000.00      0.00
1320 FINISH
```

Figure 57. CWFRAM generated input file for Example 2B

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89                                                TIME: 11:26:22

I.--HEADING
  'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
  'WITH PILE SUPPORT


               ****************
               *  INPUT DATA  *
               ****************



II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR   =         1.00
     MEMBER FORCE FACTOR =         1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =     .20
     UNIT WEIGHT OF CONCRETE            =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    6.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      42.00 (FT)
     FLOOR ELEVATION   =      23.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CENTERLINE       ELEVATION
         (FT)             (FT)
         66.00           15.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE       ELEVATION
         (FT)             (FT)
          9.75           74.50
          9.75           70.50
          4.00           65.50
          4.00           55.50
          8.00           40.00
         24.00           37.00
         24.00           21.00
         24.00           21.00
```

a. Echoprint (Continued)

Figure 58. Input data for Example 2B (Sheet 1 of 6)

III.D.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00	(FT)
CULVERT WIDTH	=	12.00	(FT)
ELEVATION AT CULVERT FLOOR	=	21.00	(FT)
CULVERT HEIGHT	=	12.00	(FT)
CULVERT FILLET SIZE	=	0.00	(FT)

III.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA
NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	BOT.	SHEAR TOP	BOT.
70.00	122.0	122.0	.600	.600	0.000	0.000

IV.B.-- LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	BOT.	SHEAR TOP	BOT.
60.00	122.0	122.0	.600	.600	0.000	0.000

V.--BASE REACTION DATA

V.A.--RIGHTSIDE PILE DATA

V.A.1.--PILE LAYOUT DATA

<------START-----> PILE NO.	DIST. FROM CENTERLINE (FT)	STOP PILE NO.	PILE NO. STEP	STEP IN CL DIST. (FT)
1	0.00	1	1	0.00
2	10.00	5	1	10.00
6	50.00	8	1	5.00
9	0.00	9	1	0.00
10	20.00	10	1	0.00
11	40.00	14	1	5.00

a. (Continued)

Figure 58. (Sheet 2 of 6)

V.A.2.--PILE PROPERTIES

PILE NO.	<------ START ------ MODULUS OF ELASTICITY (PSI)	SECT AREA (SQIN)	MOMENT OF INERTIA (IN**4)	LENGTH (FT)	AXIAL COEFF	HEAD FIXITY ------>	STOP PILE NO.	PILE NO. STEP
1	2.90E+07	21.40	729.00	45.00	1.30	0.00	14	1

V.A.3.--SOIL PROPERTIES

PILE NO.	<------ START ------ CONSTANT COEFFICIENT (PSI)	LINEAR COEFFICIENT (PCI) ------>	STOP PILE NO.	PILE NO. STEP
1	0.000	10.000	14	1

V.A.4.--PILE HEAD STIFFNESS MATRICES

NONE

V.A.4.--PILE BATTER DATA

<----START PILE NO.	BATTER (FT/FT)---->	STOP PILE NO.	PILE NO. STEP
11	3.00	14	1

V.A.5.--PILE LOAD COMPARISON DATA

V.A.5.A.--ALLOWABLE LOADS

START PILE NO.	<------ALLOWABLE AXIAL LOAD------- <-AXIAL ONLY-> COMPR. (K)	TENS. (K)	<AXIAL WITH MOM.> COMPR. (K)	TENS. (K) ------->	ALLOW. MOMENT (K-FT)	STOP PILE NO.	PILE NO. STEP
1	215.	88.	364.	364.	196.	14	1

V.A.5.B.--MOMENT/STRESS FACTORS

START PILE NO.	MOMENT MAG. FACT.	MAX. MOM. FACTOR (IN)	OVERSTRESS COMPR.	FACTOR> TENS.	STOP PILE NO.	PILE NO. STEP
1	1.000	56.600	1.330	1.330	14	1

V.B.-- LEFTSIDE PILE DATA

SYMMETRIC WITH RIGHTSIDE

VI.--WATER DATA

WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA

GROUND WATER ELEVATION = 60.00 (FT)

SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA

SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA

RIGHTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

LEFTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

a. (Continued)

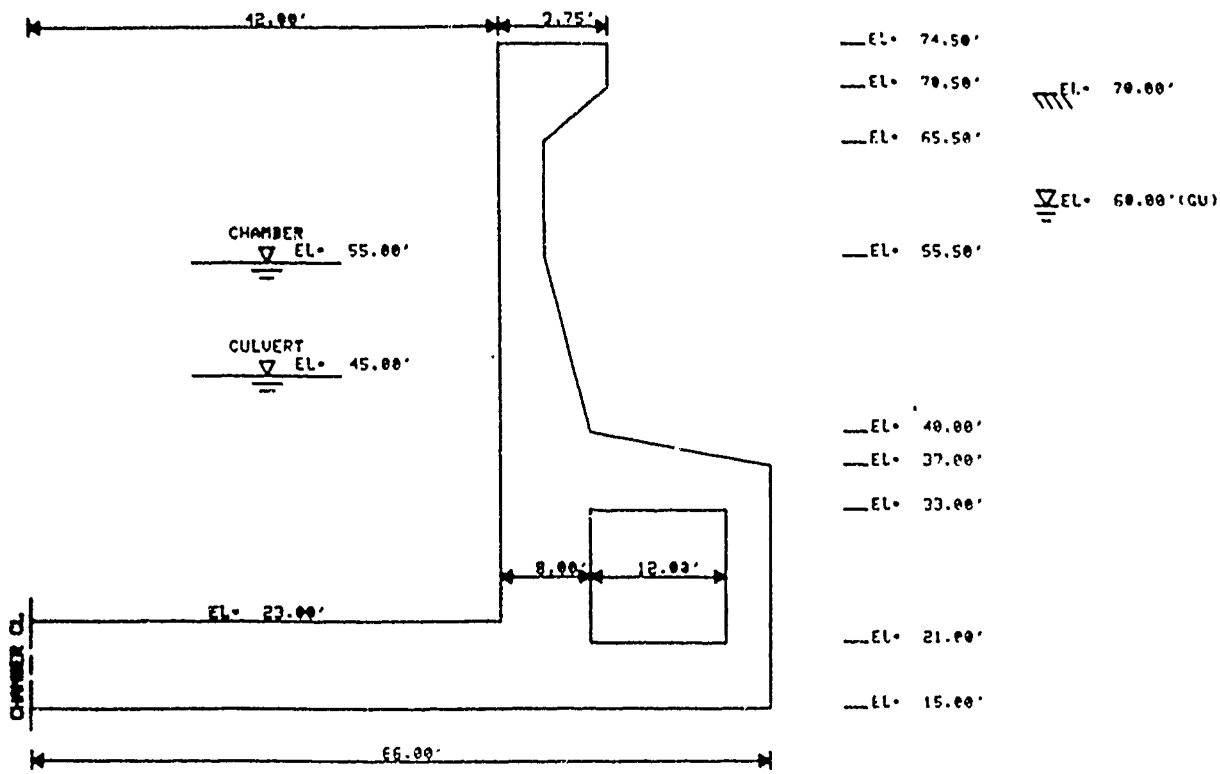
Figure 58. (Sheet 3 of 6)

```
VI.C.--INTERNAL WATER DATA
   WATER ELEVATION IN CHAMBER               =     55.00 (FT)
   WATER ELEVATION IN RIGHTSIDE CULVERT     =     45.00 (FT)
   WATER ELEVATION IN LEFTSIDE CULVERT      =     45.00 (FT)

VII.--ADDITIONAL LOAD DATA

  VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

    CONCENTRATED LOAD DATA
     ELEVATION     HORIZONTAL      VERTICAL
      AT LOAD         LOAD           LOAD
       (FT)           (PLF)          (PLF)
       70.00         1000.00          0.00

    DISTRIBUTED LOAD DATA
     NONE

  VII.A.2.--ADDITIONAL LOADS ON  LEFTSIDE EXTERNAL STEM FACE
     NONE

  VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
     NONE

  VII.B.2.--ADDITIONAL LOADS ON  LEFTSIDE INTERIOR STEM FACE
     NONE

  VII.C.1.--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
     NONE

  VII.C.2.--ADDITIONAL LOADS ON  LEFTSIDE STEM TOP
     NONE

  VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
     NONE

  VII.D.2.--ADDITIONAL LOADS ON  LEFTSIDE OF CHAMBER FLOOR
     NONE

  VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
     NONE

  VII.E.2.--ADDITIONAL LOADS ON  LEFTSIDE OF STRUCTURE BASE
     NONE

  VII.F.--EARTHQUAKE ACCELERATIONS
     NONE
```

a. (Concluded)

Figure 58. (Sheet 4 of 6)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

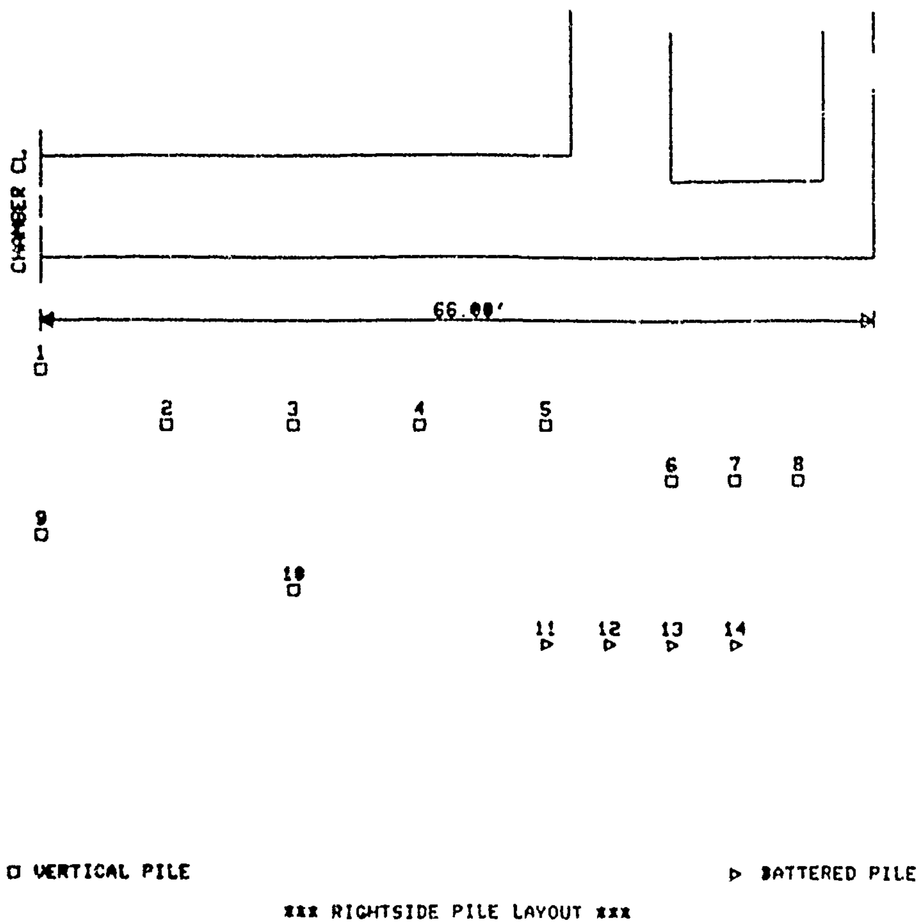


*** RIGHTSIDE ***

b. Plots of rightside geometry (Continued)

Figure 58. (Sheet 5 of 6)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT



b. (Concluded)

Figure 58. (Sheet 6 of 6)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89 TIME: 11:27:23

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

```
*************************************
*  RESULTS OF EQUILIBRIUM ANALYSIS  *
*************************************
```

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
70.000	0.	0.	0.	0.
65.500	5.4900E+02	3.2940E+02	0.	0.
60.000	1.2200E+03	7.3200E+02	0.	0.
55.500	1.4878E+03	9.9265E+02	0.	2.8125E+02
55.000	1.5175E+03	9.1050E+02	0.	3.1250E+02
40.000	2.4100E+03	1.4460E+03	0.	1.2500E+03
37.000	2.5885E+03	1.5531E+03	0.	1.4375E+03
33.000	2.8265E+03	1.6959E+03	0.	1.6875E+03
23.000	3.4215E+03	2.0529E+03	0.	2.3125E+03
21.000	3.5405E+03	2.1243E+03	0.	2.4375E+03
15.000	3.8975E+03	2.3385E+03	0.	2.6125E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	2.9375E+03
10.000	0.	2.9375E+03
20.000	0.	2.9375E+03
30.000	0.	2.9375E+03
40.000	0.	2.9375E+03
42.000	0.	2.9375E+03
45.000	0.	2.9375E+03
50.000	0.	2.9375E+03
55.000	0.	2.9375E+03
60.000	0.	2.9375E+03
62.000	0.	2.9375E+03
66.000	0.	2.9375E+

Figure 59. Results of equilibrium analysis for Example 2B (Sheet 1 of 3)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	4.3648E+05	2.7818E+05	-1.0515E+07
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
ADDL EXT STEM LOADS	6 0000E+03	0.	2.8200E+05
CONCRETE	0.	8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	6.3017E+05	6.9724E+05	-2.8599E+07

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
65.500	0.	0.	0.	0.
60.000	0.	0.	0.	0.
55.500	2.6775E+02	1.6065E+02	0.	2.8125E+02
55.000	2.9750E+02	1.7850E+02	0.	3.1250E+02
40.000	1.1900E+03	7.1400E+02	0.	1.2500E+03
37.000	1.3685E+03	8.2110E+02	0.	1.4375E+03
33.000	1.6065E+03	9.6390E+02	0.	1.6875E+03
23.000	2.2015E+03	1.3209E+03	0.	2.3125E+03
21.000	2.3205E+03	1.3923E+03	0.	2.4375E+03
15.000	2.6775E+03	1.6065E+03	0.	2.8125E+03

Figure 59. (Sheet 2 of 3)

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	2.9375E+03
10.000	0.	2.9375E+03
20.000	0.	2.9375E+03
30.000	0.	2.9375E+03
40.000	0.	2.9375E+03
42.000	0.	2.9375E+03
45.000	0.	2.9375E+03
50.000	0.	2.9375E+03
55.000	0.	2.9375E+03
60.000	0.	2.9375E+03
62.000	0.	2.9375E+03
66.000	0.	2.9375E+03

III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	2.1688E+05	1.4030E+05	-6.4746E+06
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
CONCRETE	0.	8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	4.0457E+05	5.5936E+05	-2.4841E+07

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = -2.2560E+05
TOTAL VERTICAL = 1.2566E+06
TOTAL MOMENT = -3.7581E+06

NOTE: HORIZONTAL EQUILIBRIUM PROVIDED BY FRICTION ON BASE.

V.--CONCRETE AREAS
RIGHTSIDE AREA = 9.7438E+02 (SQFT)
LEFTSIDE AREA = 9.7438E+02 (SQFT)
TOTAL AREA = 1.9488E+03 (SQFT)

Figure 59. (Sheet 3 of 3)

154. Frame model data generated by the program are shown in Figure 60. Note that joints along the base slab have been assigned at locations where one or more piles intersect the flexible portion of the structure. Piles which intersect the boundaries of the rigid blocks are assumed to be attached by rigid links to joints at the centroid of the rigid block. Plots of the frame model are included in Figure 60.

155. Results of the frame analysis are shown in Figure 61. The results include displacements of all joints in the model as well as member forces at the ends of the flexible lengths. Pile head forces and displacements, parallel and perpendicular to the axis of the pile, are given for each pile on each side. Note that the pile layout data are symmetric and that two vertical piles (piles 1 and 9) are located on the centerline. The stiffness effects of each of these piles have been evaluated only once. However, forces and displacements of the two centerline piles have been reported with the results for each side. The results of pile allowables comparisons are presented for information purposes only. The program does not attempt to assess the effect of these comparisons on the behavior of the system.

156. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.

Example 3--Type 31 Monolith

157. The symmetric system and pile layout are shown in Figure 62. The predefined input file for this system is shown in Figure 63. Note that the number identifiers assigned to the piles need not be in sequential order. Also, note that the pile/soil data initially assigned stiffness matrices representative of bending about the weak axis. The data provided subsequently for bending about the strong axis override the initial assignment. Only those piles for which layout data are provided are considered in the analysis. For illustration, uplift water is provided by an input distribution.

158. An echoprint of input data is given in Figure 64, with equilibrium results shown in Figure 65. Frame model data are given in Figure 66, and results of the frame analysis are shown in Figure 67.

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89 TIME: 11:27:47

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

```
**********************
*  FRAME MODEL DATA  *
**********************
```

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

		<------	------	CORNER	LOCATIONS	------	------>	
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	62.00	62.00	66.00	66.00	66.00	62.00	64.00
	ELEVATION	15.00	21.00	21.00	21.00	15.00	15.00	18.00
2	X-COORD.	42.00	42.00	50.00	50.00	50.00	42.00	46.00
	ELEVATION	15.00	23.00	23.00	21.00	15.00	15.00	19.00
3	X-COORD.	42.00	42.00	50.00	50.00	50.00	50.00	46.00
	ELEVATION	33.00	40.00	40.00	40.00	33.00	33.00	36.50
4	X-COORD.	62.00	62.00	66.00	66.00	66.00	66.00	63.94
	ELEVATION	33.00	37.75	37.00	33.00	33.00	33.00	35.19
6	X-COORD.	42.00	42.00	51.75	51.75	46.00	46.00	46.30
	ELEVATION	65.50	74.50	74.50	70.50	65.50	65.50	70.56

II.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	19.00000
2	10.00000	19.00000
3	20.00000	19.00000
4	30.00000	19.00000
5	40.00000	19.00000
6	46.00000	19.00000
7	55.00000	18.00000
8	60.00000	18.00000
9	64.00000	18.00000
10	63.94286	35.19286
11	46.00000	36.50000
12	44.00000	55.50000
13	46.29543	70.55508

a. Data analysis (Continued)

Figure 60. Frame model data for Example 2B (Sheet 1 of 6)

II.C.--MEMBER DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

MEM NO	FROM JT	TO JT	<COORDS AT ENDS OF FLEX LENGTH> <--FROM END--> X	ELEV	<---TO END---> X	ELEV	<-MEMBER DEPTH--> FROM END	TO END
1	1	2	0.00	19.00	10.00	19.00	8.00	8.00
2	2	3	10.00	19.00	20.00	19.00	8.00	8.00
3	3	4	20.00	19.00	30.00	19.00	8.00	8.00
4	4	5	30.00	19.00	40.00	19.00	8.00	8.00
5	5	6	40.00	19.00	42.00	19.00	8.00	8.00
6	6	7	50.00	18.00	55.00	18.00	6.00	6.00
7	7	8	55.00	18.00	60.00	18.00	6.00	6.00
8	8	9	60.00	18.00	62.00	18.00	6.00	6.00
9	9	10	64.00	21.00	64.00	33.00	4.00	4.00
10	6	11	46.00	23.00	46.00	33.00	8.00	8.00
11	11	10	50.00	36.50	62.00	35.38	7.00	4.75
12	11	12	46.00	40.00	44.00	55.50	8.00	4.00
13	12	13	44.00	55.50	44.00	65.50	4.00	4.00

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE NO.	X-COORD. (FT)	BATTER (FT/FT)	<----STIFFNESS COEFFICIENTS----> B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
2	10.00	0.00	2.6532E+05	1.7928E+07	0.	0.
3	20.00	0.00	2.6532E+05	1.7928E+07.	0.	0.
4	30.00	0.00	2.6532E+05	1.7928E+07	0.	0.
5	40.00	0.00	2.6532E+05	1.7928E+07	0.	0.
6	50.00	0.00	2.6532E+05	1.7928E+07	0.	0.
7	55.00	0.00	2.6532E+05	1.7928E+07	0.	0.
8	60.00	0.00	2.6532E+05	1.7928E+07	0.	0.
9	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
10	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
11	40.00	3.00	2.6532E+05	1.7928E+07	0.	0.
12	45.00	3.00	2.6532E+05	1.7928E+07	0.	0.
13	50.00	3.00	2.6532E+05	1.7928E+07	0.	0.
14	55.00	3.00	2.6532E+05	1.7928E+07	0.	0.

a. (Continued)

Figure 60. (Sheet 2 of 6)

III.-- LEFTSIDE FRAME MODEL DATA

III.A.--RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

BLOCK	CORNER NO.	<---CORNER LOCATIONS 1	2	3	4	5	6--->	CENTROID
1	X-COORD.	62.00	62.00	66.00	66.00	66.00	62.00	64.0C
	ELEVATION	15.00	21.00	21.00	21.00	15.00	15.00	18.00
2	X-COORD.	42.00	42.00	50.00	50.00	50.00	42.00	46.00
	ELEVATION	15.00	23.00	23.00	21.00	15.00	15.00	19.00
3	X-COORD.	42.00	42.00	50.00	50.00	50.00	50.00	46.00
	ELEVATION	33.00	40.00	40.00	40.00	33.00	33.00	36.50
4	X-COORD.	62.00	62.00	66.00	66.00	66.00	66.00	63.94
	ELEVATION	33.00	37.75	37.00	33.00	33.00	33.00	35.19
6	X-COORD.	42.00	42.00	51.75	51.75	46.00	46.00	46.30
	ELEVATION	65.50	74.50	74.50	70.50	65.50	65.50	70.56

III.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	19.00000
2	10.00000	19.00000
3	20.00000	19.00000
4	30.00000	19.00000
5	40.00000	19.00000
6	46.00000	19.00000
7	55.00000	18.00000
8	60.00000	18.00000
9	64.00000	18.00000
10	63.94286	35.19286
11	46.00000	36.50000
12	44.00000	55.50000
13	46.29543	70.55508

a. (Continued)

Figure 60. (Sheet 3 of 6)

III.C.--MEMBER DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	19.00	10.00	19.00	8.00	8.00
2	2	3	10.00	19.00	20.00	19.00	8.00	8.00
3	3	4	20.00	19.00	30.00	19.00	8.00	8.00
4	4	5	30.00	19.00	40.00	19.00	8.00	8.00
5	5	6	40.00	19.00	42.00	19.00	8.00	8.00
6	6	7	50.00	18.00	55.00	18.00	6.00	6.00
7	7	8	55.00	18.00	60.00	18.00	6.00	6.00
8	8	9	60.00	18.00	62.00	18.00	6.00	6.00
9	9	10	64.00	21.00	64.00	33.00	4.00	4.00
10	6	11	46.00	23.00	46.00	33.00	8.00	8.00
11	11	10	50.00	36.50	62.00	35.38	7.00	4.75
12	11	12	46.00	40.00	44.00	55.50	8.00	4.00
13	12	13	44.00	55.50	44.00	65.50	4.00	4.00

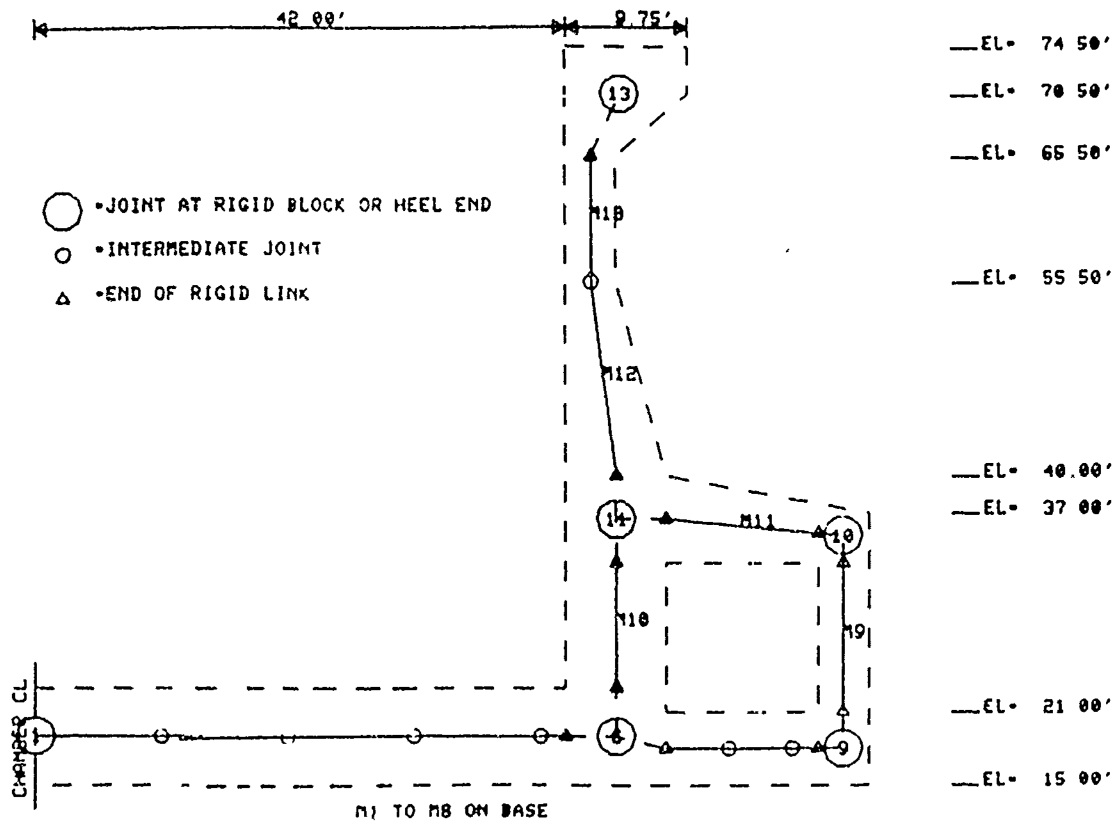
III.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE	X-COORD.	BATTER	<-------------STIFFNESS COEFFICIENTS------------->			
NO.	(FT)	(FT/FT)	B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
2	10.00	0.00	2.6532E+05	1.7928E+07	0.	0.
3	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
4	30.00	0.00	2.6532E+05	1.7928E+07	0.	0.
5	40.00	0.00	2.6532E+05	1.7928E+07	0.	0.
6	50.00	0.00	2.6532E+05	1.7928E+07	0.	0.
7	55.00	0.00	2.6532E+05	1.7928E+07	0.	0.
8	60.00	0.00	2.6532E+05	1.7928E+07	0.	0.
9	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
10	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
11	40.00	3.00	2.6532E+05	1.7928E+07	0.	0.
12	45.00	3.00	2.6532E+05	1.7928E+07	0.	0.
13	50.00	3.00	2.6532E+05	1.7928E+07	0.	0.
14	55.00	3.00	2.6532E+05	1.7928E+07	0.	0.

a. (Concluded)

Figure 60. (Sheet 4 of 6)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

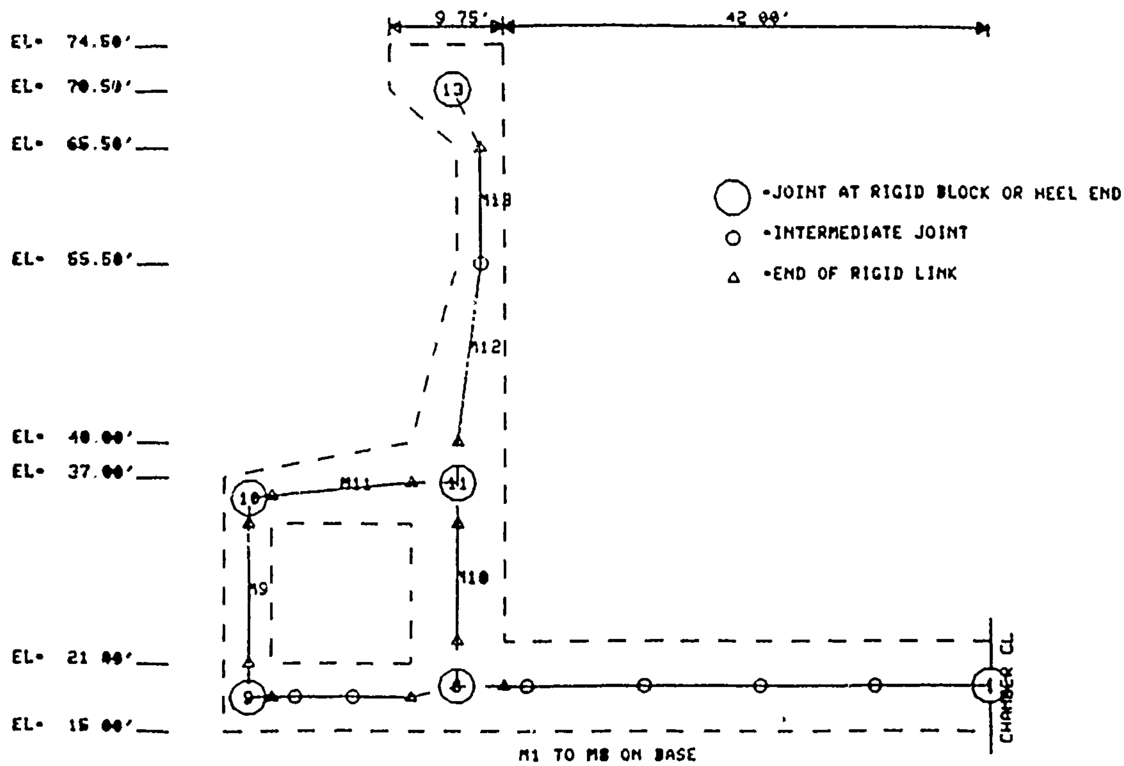


*** RIGHTSIDE MODEL ***

b. Plots of rightside geometry

Figure 60. (Sheet 5 of 6)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT



*** LEFTSIDE MODEL ***

c. Plots of leftside geometry

Figure 50. (Sheet 6 of 6)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89 TIME: 11:28:05

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

****
* RESULTS OF FRAME ANALYSIS *
****

II.--STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD STRUCTURE CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	19.00	1.551E-02	1.309E-03	-7.127E-05
2	10.00	19.00	1.580E-02	2.369E-03	-1.369E-04
3	20.00	19.00	1.608E-02	4.050E-03	-1.840E-04
4	30.00	19.00	1.637E-02	6.042E-03	-1.436E-04
5	40.00	19.00	1.666E-02	6.880E-03	8.632E-05
6	46.00	19.00	1.672E-02	6.094E-03	1.625E-04
7	55.00	18.00	1.666E-02	4.372E-03	2.329E-04
8	60.00	18.00	1.676E-02	3.094E-03	2.816E-04
9	64.00	18.00	1.680E-02	1.926E-03	3.051E-04
		***** STEM JOINTS *****			
10	63.94	35.19	2.172E-02	2.059E-03	1.320E-04
11	46.00	36.50	2.191E-02	6.402E-03	3.603E-04
12	44.00	55.50	3.147E-02	7.552E-03	6.421E-04
13	46.30	70.56	4.150E-02	6.121E-03	6.548E-04

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD STRUCTURE CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS CLOCKWISE.)

JT NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	19.00	-1.551E-02	1.309E-03	7.127E-05
2	10.00	19.00	-1.523E-02	9.272E-04	1.476E-05
3	20.00	19.00	-1.496E-02	1.002E-03	-1.970E-05
4	30.00	19.00	-1.469E-02	1.299E-03	-2.121E-05
5	40.00	19.00	-1.441E-02	1.408E-03	2.131E-05
6	46.00	19.00	-1.436E-02	1.233E-03	4.014E-05
7	55.00	18.00	-1.431E-02	8.289E-04	3.330E-05
8	60.00	18.00	-1.422E-02	7.172E-04	4.296E-05
9	64.00	18.00	-1.419E-02	5.332E-04	5.690E-05

Figure 61. Results of frame analysis for Example 2B (Sheet 1 of 5)

		***** STEM JOINTS *****			
10	63.94	35.19	-1.290E-02	6.780E-04	3.573E-05
11	46.00	36.50	-1.293E-02	1.466E-03	9.001E-05
12	44.00	55.50	-1.070E-02	1.794E-03	9.824E-05
13	46.30	70.56	-1.031E-02	1.899E-03	-1.068E-05

III.--UNFACTORED FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 2 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD STRUCTURE CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD STRUCTURE CENTERLINE.)

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	19.00	5.861E+05	1.675E+04	-7.833E+05
	10.00	19.00	5.861E+05	-9.986E+02	-6.946E+05
2	10.00	19.00	5.905E+05	4.348E+04	-7.119E+05
	20.00	19.00	5.905E+05	-2.773E+04	-3.559E+05
3	20.00	19.00	5.994E+05	1.730E+05	-3.916E+05
	30.00	19.00	5.994E+05	-1.572E-05	1.259E+06
4	30.00	19.00	6.039E+05	2.655E+05	1.241E+06
	40.00	19.00	6.039E+05	-2.498E+05	3.818E+06
5	40.00	19.00	6.049E+05	3.979E+05	3.814E+06
	42.00	19.00	6.049E+05	-3.947E+05	4.606E+06
6	50.00	18.00	3.062E+05	-8.067E+04	8.459E+05
	55.00	18.00	3.062E+05	6.454E+04	4.828E+05
7	55.00	18.00	3.197E+05	-5.082E+01	4.424E+05
	60.00	18.00	3.197E+05	-1.607E+04	4.824E+05
8	60.00	18.00	3.239E+05	7.155E+04	4.698E+05
	62.00	18.00	3.239E+05	-7.800E+04	6.193E+05
		***** CULVERT MEMBERS *****			
9	64.00	21.00	1.269E+05	-1.491E+05	3.387E+05
	64.00	33.00	8.370E+04	-5.595E+04	-1.891E+05
10	46.00	23.00	6.752E+05	-2.890E+05	3.699E+06
	46.00	33.00	6.032E+05	3.265E+05	6.215E+05
11	50.00	36.50	1.538E+05	3.262E+05	-2.102E+06
	62.00	35.38	1.425E+05	-4.106E+04	-3.994E+03
		***** STEM MEMBERS *****			
12	46.00	40.00	2.159E+05	-2.209E+05	2.142E+06
	44.00	55.50	8.587E+04	6.522E+04	1.926E+05
13	44.00	55.50	9.351E+04	-5.369E+04	1.926E+05
	44.00	65.50	5.751E+04	1.045E+04	-8.617E+04

Figure 61. (Sheet 2 of 5)

III.B.-- LEFTSIDE MEMBERS - TYPE 2 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD STRUCTURE CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD STRUCTURE CENTERLINE.)

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	19.00	5.777E+05	3.021E+04	-7.498E+05
	10.00	19.00	5.777E+05	-1.446E+04	-5.265E+05
2	10.00	19.00	5.737E+05	3.108E+04	-5.103E+05
	20.00	19.00	5.737E+05	-1.533E+04	-2.782E+05
3	20.00	19.00	5.658E+05	5.124E+04	-2.466E+05
	30.00	19.00	5.658E+05	-3.549E+04	1.870E+05
4	30.00	19.00	5.619E+05	5.878E+04	2.025E+05
	40.00	19.00	5.619E+05	-4.303E+04	7.116E+05
5	40.00	19.00	5.212E+05	1.679E+05	8.747E+05
	42.00	19.00	5.212E+05	-1.647E+05	1.207E+06
6	50.00	18.00	3.026E+05	-6.010E+04	7.295E+04
	55.00	18.00	3.026E+05	4.398E+04	-1.873E+05
7	55.00	18.00	2.651E+05	6.062E+04	-7.480E+04
	60.00	18.00	2.651E+05	-7.674E+04	2.686E+05
8	60.00	18.00	2.613E+05	8.960E+04	2.800E+05
	62.00	18.00	2.613E+05	-9.605E+04	4.657E+05
		***** CULVERT MEMBERS *****			
9	64.00	21.00	1.450E+05	-1.128E+05	3.300E+05
	64.00	33.00	1.018E+05	-3.953E+04	-7.874E+04
10	46.00	23.00	5.193E+05	-1.260E+05	1.244E+06
	46.00	33.00	4.473E+05	1.635E+05	-2.037E+05
11	50.00	36.50	1.195E+05	1.872E+05	-9.653E+05
	62.00	35.38	1.098E+05	9.546E+03	1.928E+04
		***** STEM MEMBERS *****			
12	46.00	40.00	2.101E+05	-1.034E+05	6.147E+05
	44.00	55.50	1.004E+05	1.897E+04	-1.426E+05
13	44.00	55.50	1.020E+05	-5.966E+03	-1.426E+05
	44.00	65.50	6.604E+04	0.	-1.516E+05

Figure 61. (Sheet 3 of 5)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/06/89 TIME: 11:28:06

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

II.--RESULTS FOR RIGHTSIDE PILES

II.A.--PILE HEAD FORCES AND DISPLACEMENTS
(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS--->		
NO.	CTR-LINE	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	2.348E+04	-4.192E+03	0.	1.309E-03	-1.580E-02	-7.127E-05
2	10.00	4.248E+04	-4.336E+03	0.	2.369E-03	-1.634E-02	-1.369E-04
3	20.00	7.261E+04	-4.462E+03	0.	4.050E-03	-1.682E-02	-1.840E-04
4	30.00	1.083E+05	-4.496E+03	0.	6.042E-03	-1.694E-02	-1.436E-04
5	40.00	1.233E+05	-4.329E+03	0.	6.880E-03	-1.632E-02	8.632E-05
6	50.00	9.760E+04	-4.264E+03	0.	5.444E-03	-1.607E-02	1.625E-04
7	55.00	7.838E+04	-4.234E+03	0.	4.372E-03	-1.596E-02	2.329E-04
8	60.00	5.548E+04	-4.222E+03	0.	3.094E-03	-1.591E-02	2.818E-04
9	0.00	2.348E+04	-4.192E+03	0.	1.309E-03	-1.580E-02	-7.127E-05
10	20.00	7.261E+04	-4.462E+03	0.	4.050E-03	-1.682E-02	-1.840E-04
11	40.00	2.452E+04	-4.684E+03	0.	1.368E-03	-1.765E-02	8.632E-05
12	45.00	1.531E+04	-4.570E+03	0.	8.537E-04	-1.722E-02	1.625E-04
13	50.00	1.489E+03	-4.501E+03	0.	8.306E-05	-1.697E-02	1.625E-04
14	55.00	-1.610E+04	-4.383E+03	0.	-8.982E-04	-1.652E-02	2.329E-04

II.B.--PILE ALLOWABLES COMPARISONS

PILE NO.	DIST. TO CTR-LINE (FT)	MAXIMUM MOMENT (LB-FT)	<ALLOWABLES COMPARISON RATIOS> AXIAL FORCE ONLY	AXIAL FORCE AND MOMENT
1	0.00	1.98E+04	.082	.124
2	10.00	2.05E+04	.149	.166
3	20.00	2.10E+04	.254	.231
4	30.00	2.12E+04	.379	.305
5	40.00	2.04E+04	.431	.333
6	50.00	2.01E+04	.341	.279
7	55.00	2.00E+04	.274	.239
8	60.00	1.99E+04	.194	.191
9	0.00	1.98E+04	.082	.124
10	20.00	2.10E+04	.254	.231
11	40.00	2.21E+04	.086	.135
12	45.00	2.16E+04	.054	.114
13	50.00	2.12E+04	.005	.085
14	55.00	2.07E+04	.138	.113

Figure 61. (Sheet 4 of 5)

III.--RESULTS FOR LEFTSIDE PILES

III.A.--PILE HEAD FORCES AND DISPLACEMENTS

(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS--->		
NO.	CTR-LINE	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	2.348E+04	4.192E+03	0.	1.309E-03	1.580E-02	7.127E-05
2	10.00	1.662E+04	4.058E+03	0.	9.272E-04	1.529E-02	1.476E-05
3	20.00	1.796E+04	3.948E+03	0.	1.002E-03	1.488E-02	-1.970E-05
4	30.00	2.329E+04	3.874E+03	0.	1.299E-03	1.460E-02	-2.121E-05
5	40.00	2.524E+04	3.847E+03	0.	1.408E-03	1.450E-02	2.131E-05
6	50.00	1.922E+04	3.854E+03	0.	1.072E-03	1.452E-02	4.014E-05
7	55.00	1.486E+04	3.822E+03	0.	8.289E-04	1.441E-02	3.330E-05
8	60.00	1.286E+04	3.807E+03	0.	7.172E-04	1.435E-02	4.296E-05
9	0.00	2.348E+04	4.192E+03	0.	1.309E-03	1.580E-02	7.127E-05
10	20.00	1.796E+04	3.948E+03	0.	1.002E-03	1.488E-02	-1.970E-05
11	40.00	1.061E+05	3.531E+03	0.	5.921E-03	1.331E-02	2.131E-05
12	45.00	1.040E+05	3.549E+03	0.	5.801E-03	1.338E-02	4.014E-05
13	50.00	1.006E+05	3.566E+03	0.	5.610E-03	1.344E-02	4.014E-05
14	55.00	9.578E+04	3.557E+03	0.	5.342E-03	1.341E-02	3.330E-05

III.B.--PILE ALLOWABLES COMPARISONS

PILE NO.	DIST. TO CTR-LINE (FT)	MAXIMUM MOMENT (LB-FT)	<ALLOWABLES COMPARISON RATIOS> AXIAL FORCE ONLY	AXIAL FORCE AND MOMENT
1	0.00	-1.98E+04	.082	.124
2	10.00	-1.91E+04	.058	.108
3	20.00	-1.86E+04	.063	.109
4	30.00	-1.83E+04	.081	.118
5	40.00	-1.81E+04	.088	.122
6	50.00	-1.82E+04	.067	.109
7	55.00	-1.80E+04	.052	.100
8	60.00	-1.80E+04	.045	.095
9	0.00	-1.98E+04	.082	.124
10	20.00	-1.86E+04	.063	.109
11	40.00	-1.67E+04	.371	.283
12	45.00	-1.67E+04	.364	.279
13	50.00	-1.68E+04	.352	.272
14	55.00	-1.68E+04	.335	.262

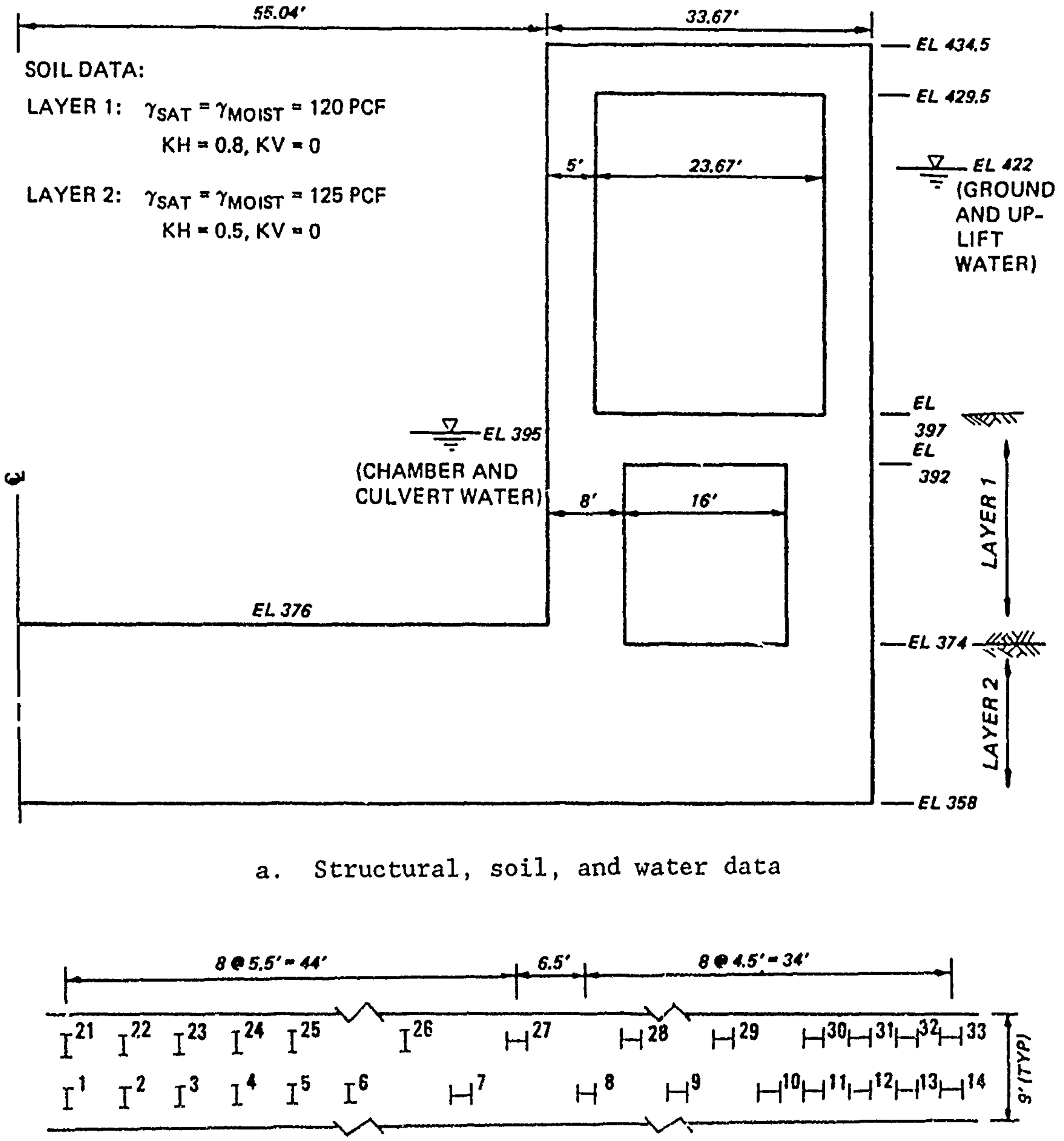
IV.--RESULTANTS OF PILE FORCES ON STRUCTURE

(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE
(UNITS ARE POUNDS AND FEET)

	HORIZONTAL	VERTICAL	MOMENT
RIGHTSIDE PILES	4.8230E+04	7.0397E+05	2.5505E+07
LEFTSIDE PILES	1.7737E+05	5.5263E+05	-2.1746E+07
TOTAL	2.2560E+05	1.2566E+06	3.7581E+06

NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CENTERLINE.

Figure 61. (Sheet 5 of 5)



a. Structural, soil, and water data

b. Pile layout

Figure 62. System for Example 3

***** INPUT FILE FOR EXAMPLE 3 *****

```
1000  'EXAMPLE 3 - TYPE MONOLITH
1010 METHOD  FR       1.00        1.00
1020 STRUCTURE    3.00E+06         .20      150.00        9.00
1030 FLOOR           55.04      376.00         .00
1040 BASE  BOTH                  88.71      358.00
1050 STEM  BOTH              7
1060        33.67   434.50       33.67      431.75       33.67     429.50
1070        33.67   397.00       33.67      392.00       33.67     374.00
1080        33.67   374.00
1090 CULVERT  BOTH                8.00       16.00      374.00      18.00       .00
1100 VOIDS  BOTH                  5.00       23.67      397.00      32.50         0
1110 BACKFILL  BOTH      SOIL        2         .00
1120       397.00   120.00      120.00         .80         .80        .00       .00
1130       374.00   125.00      125.00         .50         .50        .00       .00
1140 REACTION PILES
1150 PILES  BOTH
1160 LAYOUT          1             .00    6     1        5.50
1170 LAYOUT          7           38.50    8     1       12.00
1180 LAYOUT          9           59.50    9     1        [illegible].00
1190 LAYOUT         10           68.50   14     1        4.50
1200 LAYOUT         21             .00   25     1        5.50
1210 LAYOUT         26           33.00   27     1       11.00
1220 LAYOUT         28           55.00   29     1        9.00
1230 LAYOUT         30           73.00   33     1        4.50
1240 (STIFFNESS MATRICES FOR BENDING ABOUT WEAK AXIS)
1250 STIFF     1  5.490E+05  2.000E+07  2.320E+07  2.770E+06   50    1
1260 (STIFFNESS MATRICES FOR BENDING ABOUT STRONG AXIS)
1270 STIFF     7  8.230E+05  2.000E+07  5.230E+07  5.090E+06   14    1
1280 STIFF    27  8.230E+05  2.000E+07  5.230E+07  5.090E+06   33    1
1290 WATER             62.5
1300 EXTERNAL  BOTH      ELEVATION      422.00
1310 UPLIFT PRESSURE
1320  BOTH               2                     .00   4000.00     100.00   4000.00
1330 INTERNAL      395.00      395.00      395.00
1340 FINISH
```

Figure 63. Input file for Example 3

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/07/89                                                TIME: 15:01:51

I.--HEADING
  'EXAMPLE 3 - TYPE 31 MONOLITH

               ****************
               *  INPUT DATA  *
               ****************


II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR   =         1.00
     MEMBER FORCE FACTOR =         1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE   =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE        =     .20
     UNIT WEIGHT OF CONCRETE             =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE  =    9.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      55.04 (FT)
     FLOOR ELEVATION   =     376.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CENTERLINE      ELEVATION
         (FT)           (FT)
         88.71         358.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE      ELEVATION
         (FT)           (FT)
         33.67         434.50
         33.67         431.75
         33.67         429.50
         33.67         397.00
         33.67         392.00
         33.67         374.00
         33.67         374.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

Figure 64. Echoprint of input data for Example 3 (Sheet 1 of 3)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00 (FT)
CULVERT WIDTH	=	16.00 (FT)
ELEVATION AT CULVERT FLOOR	=	374.00 (FT)
CULVERT HEIGHT	=	18.00 (FT)
CULVERT FILLET SIZE	=	0.00 (FT)

III.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA

III.F.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	5.00 (FT)
VOID WIDTH	=	23.67 (FT)
ELEVATION AT VOID BOTTOM	=	397.00 (FT)
VOID HEIGHT	=	32.50 (FT)
VOID TIES		NONE

III.F.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	BOT.	SHEAR TOP	BOT.
397.00	120.0	120.0	.800	.800	0.000	0.000
374.00	125.0	125.0	.500	.500	0.000	0.000

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

V.A.--RIGHTSIDE PILE DATA

V.A.1.--PILE LAYOUT DATA

<------START-----> PILE NO.	DIST. FROM CENTERLINE (FT)	STOP PILE NO.	PILE NO. STEP	STEP IN CL DIST. (FT)
1	0.00	6	1	5.50
7	38.50	8	1	12.00
9	59.50	9	1	0.00
10	68.50	14	1	4.50
21	0.00	25	1	5.50
26	33.00	27	1	11.00
28	55.00	29	1	9.00
30	73.00	33	1	4.50

Figure 64. (Sheet 2 of 3)

V.A.2.--PILE PROPERTIES
NONE

V.A.3.--SOIL PROPERTIES
NONE

V.A.4.--PILE HEAD STIFFNESS MATRICES

<------START------>					STOP	PILE
PILE	<----STIFFNESS COEFFICIENTS---->				PILE	NO.
NO.	B11 (LB/IN)	B22 (LB/IN)	B33 (LB-IN)	B13 (LB)	NO.	STEP
1	5.490E+05	2.000E+07	2.320E+07	2.770E+06	50	1
7	8.230E+05	2.000E+07	5.230E+07	5.090E+06	14	1
27	8.230E+C5	2.000E+07	5.230E+07	5.090E+06	33	1

V.A.4.--PILE BATTER DATA
NONE

V.A.5.--PILE LOAD COMPARISON DATA
NONE

V.B.-- LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 422.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA

VI.B.1.--RIGHTSIDE UPLIFT WATER PRESSURE DISTRIBUTION

DIST. FROM CENTERLINE (FT)	UPLIFT PRESSURE (PSF)
0.00	4000.00
100.00	4000.00

VI.B.2.-- LEFTSIDE UPLIFT WATER PRESSURE DISTRIBUTION
SYMMETRIC WITH RIGHTSIDE

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 395.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 395.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 395.00 (FT)

VII.--ADDITIONAL LOAD DATA
NONE

Figure 64. (Sheet 3 of 3)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/07/89 TIME: 15:02:10

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

****
* RESULTS OF EQUILIBRIUM ANALYSIS *
****

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
434.500	0.	0.	0.	0.
431.750	0.	0.	0.	0.
429.500	0.	0.	0.	0.
422.000	0.	0.	0.	0.
397.000	0.	0.	0.	1.5625E+03
395.000	1.1500E+02	9.2000E+01	0.	1.6875E+03
392.000	2.8750E+02	2.3000E+02	0.	1.8750E+03
376.000	1.2075E+03	9.6600E+02	0.	2.8750E+03
374.000+	1.3225E+03	1.0580E+03	0.	3.0000E+03
374.000-	1.3225E+03	6.6125E+02	0.	3.0000E+03
358.000	2.3225E+03	1.1613E+03	0.	4.0000E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	4.0000E+03
5.500	0.	4.0000E+03
11.000	0.	4.0000E+03
16.500	0.	4.0000E+03
22.000	0.	4.0000E+03
27.500	0.	4.0000E+03
33.000	0.	4.0000E+03
38.500	0.	4.0000E+03
44.000	0.	4.0000E+03
50.500	0.	4.0000E+03
55.000	0.	4.0000E+03
55.040	0.	4.0000E+03
59.500	0.	4.0000E+03
63.040	0.	4.0000E+03
64.000	0.	4.0000E+03
68.500	0.	4.0000E+03
73.000	0.	4.0000E+03
77.500	0.	4.0000E+03
79.040	0.	4.0000E+03
82.000	0.	4.0000E+03
86.500	0.	4.0000E+03
88.710	0.	4.0000E+03

Figure 65. Results of equilibrium analysis for Example 3 (Continued)

```
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
  (POSITIVE VERTICAL IS DOWN)
  (POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
  (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER
       FLOOR CENTERLINE)
  (UNITS ARE POUNDS AND FEET)

       ITEM                HORIZONTAL   VERTICAL      MOMENT
  BACKFILL                 2.4072E+05   0.           -7.8768E+05
  GROUND/SURCH WATER       1.1520E+06   0.            3.8400E+06
  INTERNAL WATER          -1.0153E+05   7.5024E+05   -2.8340E+07
  UPLIFT WATER             0.          -3.1936E+06    1.4165E+08
  CONCRETE                 0.           3.3874E+06   -1.8447E+08
  TOTAL THIS SIDE          1.2912E+06   9.4410E+05   -6.8109E+07


III.--EFFECTS ON STRUCTURE  LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE


IV.--NET RESULTANTS OF ALL LOADS
     (POSITIVE HORIZONTAL IS TO THE RIGHT)
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
     (UNITS ARE POUNDS AND FEET)
          TOTAL HORIZONTAL =   0.
          TOTAL VERTICAL   =   1.8882E+06
          TOTAL MOMENT     =   0.


 V.--CONCRETE AREAS
     RIGHTSIDE AREA =  2.5092E+03 (SQFT)
      LEFTSIDE AREA =  2.5092E+03 (SQFT)
     TOTAL AREA     =  5.0184E+03 (SQFT)
```

Figure 65. (Concluded)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/07/89 TIME: 15:02:21

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

****
* FRAME MODEL DATA *
****

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 31 MONOLITH
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

		<---	---------CORNER	LOCATIONS---------			-------->	
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	79.04	79.04	88.71	88.71	88.71	79.04	83.87
	ELEVATION	358.00	374.00	374.00	374.00	358.00	358.00	366.00
2	X-COORD.	55.04	55.04	63.04	63.04	63.04	55.04	59.04
	ELEVATION	358.00	376.00	376.00	374.00	358.00	358.00	367.00
3	X-COORD.	55.04	55.04	60.04	63.04	63.04	63.04	59.04
	ELEVATION	392.00	397.00	397.00	397.00	392.00	392.00	394.50
4	X-COORD.	79.04	79.04	88.71	88.71	88.71	88.71	83.88
	ELEVATION	392.00	397.00	397.00	397.00	392.00	392.00	394.50
5	X-COORD.	55.04	55.04	60.04	60.04	60.04	60.04	57.54
	ELEVATION	429.50	434.50	434.50	429.50	429.50	429.50	432.00
6	X-COORD.	83.71	83.71	88.71	88.71	88.71	88.71	86.21
	ELEVATION	429.50	434.50	434.50	431.75	429.50	429.50	432.00

II.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	367.00000
2	5.50000	367.00000
3	11.00000	367.00000
4	16.50000	367.00000
5	22.00000	367.00000
6	27.50000	367.00000
7	33.00000	367.00000
8	38.50000	367.00000
9	44.00000	367.00000
10	50.50000	367.00000
11	55.00000	367.00000
12	59.04000	367.00000
13	64.00000	366.00000
14	68.50000	366.00000
15	73.00000	366.00000
16	77.50000	366.00000
17	83.87500	366.00000
18	83.87500	394.50000
19	86.21000	432.00000
20	59.04000	394.50000
21	57.54000	432.00000

Figure 66. Frame model data for Example 3 (Continued)

II.C.--MEMBER DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	367.00	5.50	367.00	18.00	18.00
2	2	3	5.50	367.00	11.00	367.00	18.00	18.00
3	3	4	11.00	367.00	16.50	367.00	18.00	18.00
4	4	5	16.50	367.00	22.00	367.00	18.00	18.00
5	5	6	22.00	367.00	27.50	367.00	18.00	18.00
6	6	7	27.50	367.00	33.00	367.00	18.00	18.00
7	7	8	33.00	367.00	38.50	367.00	18.00	18.00
8	8	9	38.50	367.00	44.00	367.00	18.00	18.00
9	9	10	44.00	367.00	50.50	367.00	18.00	18.00
10	10	11	50.50	367.00	55.00	367.00	18.00	18.00
11	11	12	55.00	367.00	55.04	367.00	18.00	18.00
12	12	13	63.04	366.00	64.00	366.00	16.00	16.00
13	13	14	64.00	366.00	68.50	366.00	16.00	16.00
14	14	15	68.50	366.00	73.00	366.00	16.00	16.00
15	15	16	73.00	366.00	77.50	366.00	16.00	16.00
16	16	17	77.50	366.00	79.04	366.00	16.00	16.00
17	17	18	83.88	374.00	83.88	392.00	9.67	9.67
18	18	19	86.21	397.00	86.21	429.50	5.00	5.00
19	12	20	59.04	376.00	59.04	392.00	8.00	8.00
20	20	21	57.54	397.00	57.54	429.50	5.00	5.00
21	20	18	63.04	394.50	79.04	394.50	5.00	5.00
22	21	19	60.04	432.00	83.71	432.00	5.00	5.00

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE	X-COORD.	BATTER	<-------------STIFFNESS	COEFFICIENTS	------------->	
NO.	(FT)	(FT/FT)	B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
2	5.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
3	11.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
4	16.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
5	22.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
6	27.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
7	38.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
8	50.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
9	59.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
10	68.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
11	73.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
12	77.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
13	82.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
14	86.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
21	0.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
22	5.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
23	11.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
24	16.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
25	22.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
26	33.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
27	44.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
28	55.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
29	64.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
30	73.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
31	77.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
32	82.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
33	86.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

Figure 66. (Concluded)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/07/89 TIME: 15:02:31

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

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********************************
*  RESULTS OF FRAME ANALYSIS   *
********************************
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II.--STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 31 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD STRUCTURE CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	367.00	0.	-2.339E-05	0.
2	5.50	367.00	9.011E-05	-1.975E-05	-1.565E-06
3	11.00	367.00	1.803E-04	-8.092E-06	-3.245E-06
4	16.50	367.00	2.708E-04	1.367E-05	-5.096E-06
5	22.00	367.00	3.615E-04	4.871E-05	-7.046E-06
6	27.50	367.00	4.527E-04	1.007E-04	-8.805E-06
7	33.00	367.00	5.442E-04	1.674E-04	-9.846E-06
8	38.50	367.00	6.360E-04	2.469E-04	-9.584E-06
9	44.00	367.00	7.284E-04	3.343E-04	-7.216E-06
10	50.50	367.00	8.383E-04	4.314E-04	-7.556E-09
11	55.00	367.00	9.149E-04	4.823E-04	8.709E-06
12	59.04	367.00	9.156E-04	4.475E-04	8.803E-06
13	64.00	366.00	9.217E-04	4.002E-04	1.019E-05
14	68.50	366.00	9.918E-04	3.477E-04	1.660E-05
15	73.00	366.00	1.063E-03	2.843E-04	2.404E-05
16	77.50	366.00	1.135E-03	2.133E-04	3.413E-05
17	83.87	366.00	1.160E-03	-9.294E-07	3.850E-05
		***** OUTSIDE STEM JOINTS *****			
18	83.88	394.50	3.189E-03	1.899E-04	6.475E-05
19	86.21	432.00	7.025E-03	3.898E-04	8.867E-05
		***** INSIDE STEM JOINTS *****			
20	59.04	394.50	3.022E-03	7.930E-04	1.110E-04
21	57.54	432.00	6.996E-03	1.355E-03	7.228E-06

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 31 MONOLITH
SYMMETRIC WITH RIGHTSIDE

Figure 67. Results of frame analysis for Example 3 (Sheet 1 of 3)

III.--UNFACTORED FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 31 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD STRUCTURE CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD STRUCTURE CENTERLINE.)

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
			***** BASE MEMBERS *****		
1	0.00	367.00	1.147E+06	-5.614E+03	-5.275E+05
	5.50	367.00	1.147E+06	4.505E+01	-5.431E+05
2	5.50	367.00	1.148E+06	-9.524E+03	-5.561E+05
	11.00	367.00	1.148E+06	3.955E+03	-5.931E+05
3	11.00	367.00	1.151E+06	-7.839E+03	-6.193E+05
	16.50	367.00	1.151E+06	2.270E+03	-6.471E+05
4	16.50	367.00	1.155E+06	4.290E+03	-6.867E+05
	22.00	367.00	1.155E+06	-9.859E+03	-6.478E+05
5	22.00	367.00	1.161E+06	3.324E+04	-7.009E+05
	27.50	367.00	1.161E+06	-3.881E+04	-5.028E+05
6	27.50	367.00	1.164E+06	6.298E+04	-5.260E+05
	33.00	367.00	1.164E+06	-6.855E+04	-1.743E+05
7	33.00	367.00	1.168E+06	1.087E+05	-2.139E+05
	38.50	367.00	1.168E+06	-1.143E+05	3.994E+05
8	38.50	367.00	1.175E+06	1.735E+05	3.310E+05
	44.00	367.00	1.175E+06	-1.791E+05	1.301E+06
9	44.00	367.00	1.183E+06	2.593E+05	1.226E+06
	50.50	367.00	1.183E+06	-2.659E+05	2.933E+06
10	50.50	367.00	1.192E+06	3.694E+05	2.854E+06
	55.00	367.00	1.192E+06	-3.740E+05	4.527E+06
11	55.00	367.00	1.200E+06	4.897E+05	4.449E+06
	55.04	367.00	1.200E+06	-4.898E+05	4.468E+06
12	63.04	366.00	9.619E+05	-6.822E+04	1.948E+06
	64.00	366.00	9.619E+05	6.573E+04	1.883E+06
13	64.00	366.00	9.701E+05	3.032E+04	1.813E+06
	68.50	366.00	9.701E+05	-4.197E+04	1.976E+06
14	68.50	366.00	9.785E+05	1.254E+05	1.904E+06
	73.00	366.00	9.785E+05	-1.371E+05	2.495E+06
15	73.00	366.00	9.955E+05	2.735E+05	2.351E+06
	77.50	366.00	9.955E+05	-2.852E+05	3.608E+06
16	77.50	366.00	1.012E+06	3.876E+05	3.466E+06
	79.04	366.00	1.012E+06	-3.915E+05	4.066E+06
			***** OUTSIDE STEM MEMBERS *****		
17	83.88	374.00	5.160E+05	-4.098E+05	2.382E+06
	83.88	392.00	2.811E+05	3.208E+04	-8.939E+05
18	86.21	397.00	3.197E+05	-1.525E+05	8.344E+05
	86.21	429.50	1.003E+05	-2.330E+04	1.267E+05
			***** INSIDE STEM MEMBERS *****		
19	59.04	376.00	7.580E+05	-2.237E+05	2.849E+06
	59.04	392.00	5.852E+05	2.237E+05	-7.302E+05
20	57.54	397.00	3.463E+05	-2.330E+04	2.493E+05
	57.54	429.50	1.269E+05	2.330E+04	-5.079E+05
			***** CULVERT ROOF *****		
21	63.04	394.50	2.029E+05	1.849E+05	-1.380E+06
	79.04	394.50	2.029E+05	-1.039E+05	9.305E+05
			***** VOID ROOF *****		
22	60.04	432.00	2.330E+04	9.318E+04	-3.332E+05
	83.71	432.00	2.330E+04	6.659E+04	-1.345E+04

III.B.-- LEFTSIDE MEMBERS - TYPE 31 MONOLITH
SYMMETRIC WITH RIGHTSIDE

Figure 67. (Sheet 2 of 3)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/07/89 TIME: 15:02:31

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

II.--RESULTS FOR RIGHTSIDE PILES

II.A.--PILE HEAD FORCES AND DISPLACEMENTS
(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS--->		
NO.	CTR-LINE	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	-5.614E+03	0.	0.	-2.339E-05	0.	0.
2	5.50	-4.739E+03	-6.908E+02	-2.917E+02	-1.975E-05	-1.042E-04	-1.565E-06
3	11.00	-1.942E+03	-1.389E+03	-5.867E+02	-8.092E-06	-2.095E-04	-3.245E-06
4	16.50	3.280E+03	-2.100E+03	-8.869E+02	1.367E-05	-3.166E-04	-5.096E-06
5	22.00	1.169E+04	-2.819E+03	-1.191E+03	4.871E-05	-4.249E-04	-7.046E-06
6	27.50	2.417E+04	-3.529E+03	-1.491E+03	1.007E-04	-5.320E-04	-8.805E-06
7	38.50	5.925E+04	-7.182E+03	-3.718E+03	2.469E-04	-7.223E-04	-9.584E-06
8	50.50	1.035E+05	-8.286E+03	-4.271E+03	4.314E-04	-8.390E-04	-7.556E-08
9	59.50	1.064E+05	-8.215E+03	-4.219E+03	4.435E-04	-8.364E-04	8.803E-06
10	68.50	8.345E+04	-8.400E+03	-4.300E+03	3.477E-04	-8.591E-04	1.660E-05
11	73.00	6.824E+04	-8.473E+03	-4.325E+03	2.843E-04	-8.703E-04	2.404E-05
12	77.50	5.118E+04	-8.336E+03	-4.237E+03	2.133E-04	-8.616E-04	3.413E-05
13	82.00	1.710E+04	-8.216E+03	-4.167E+03	7.125E-05	-8.517E-04	3.850E-05
14	86.50	-2.448E+04	-8.216E+03	-4.167E+03	-1.020E-04	-8.517E-04	3.850E-05
21	0.00	-5.614E+03	0.	0.	-2.339E-05	0.	0.
22	5.50	-4.739E+03	-6.908E+02	-2.917E+02	-1.975E-05	-1.042E-04	-1.565E-06
23	11.00	-1.942E+03	-1.389E+03	-5.867E+02	-8.092E-06	-2.095E-04	-3.245E-06
24	16.50	3.280E+03	-2.100E+03	-8.869E+02	1.367E-05	-3.166E-04	-5.096E-06
25	22.00	1.169E+04	-2.819E+03	-1.191E+03	4.871E-05	-4.249E-04	-7.046E-06
26	33.00	4.017E+04	-4.196E+03	-1.772E+03	1.674E-04	-6.328E-04	-9.846E-06
27	44.00	8.022E+04	-7.872E+03	-4.070E+03	3.343E-04	-7.934E-04	-7.216E-06
28	55.00	1.158E+05	-8.218E+03	-4.220E+03	4.823E-04	-8.366E-04	8.709E-06
29	64.00	9.605E+04	-8.246E+03	-4.232E+03	4.002E-04	-8.402E-04	1.019E-05
30	73.00	6.824E+04	-8.473E+03	-4.325E+03	2.843E-04	-8.703E-04	2.404E-05
31	77.50	5.118E+04	-8.336E+03	-4.237E+03	2.133E-04	-8.616E-04	3.413E-05
32	82.00	1.710E+04	-8.216E+03	-4.167E+03	7.125E-05	-8.517E-04	3.850E-05
33	86.50	-2.448E+04	-8.216E+03	-4.167E+03	-1.020E-04	-8.517E-04	3.850E-05

II.B.--PILE ALLOWABLES COMPARISONS
ALLOWABLES DATA NOT PROVIDED FOR THIS SIDE.

III.--RESULTS FOR LEFTSIDE PILES
SYMMETRIC WITH RIGHTSIDE.

IV.--RESULTANTS OF PILE FORCES ON STRUCTURE
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE
(UNITS ARE POUNDS AND FEET)

	HORIZONTAL	VERTICAL	MOMENT
RIGHTSIDE PILES	1.4462E+05	9.4410E+05	5.7262E+07
LEFTSIDE PILES	-1.4462E+05	9.4410E+05	-5.7262E+07
TOTAL	0.	1.8882E+06	0.

NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CENTERLINE.

Figure 67. (Sheet 3 of 3)

Example 4--Nonconforming Monolith

159. The monolith shown in Figure 68 does not conform to the geometric requirements for frame analysis for type 2 or type 3 monoliths. However, this geometry is admissible for equilibrium analysis.

160. The predefined input file for the symmetric, soil-supported system is shown in Figure 69 and an echoprint of the input is given in Figure 70. The results of the equilibrium analysis are given in Figure 71.

Example 5--Type 1 Monolith Combined with a C5 Monolith

161. Any of the monoliths described above may be combined with a center stem monolith (C1 through C9) to produce a W-frame structure. The combination of type 1 monolith from example 1 (Figure 44) and a C5 monolith are shown in Figure 72.

162. The predefined input file for the symmetric, soil-supported system is shown in Figure 73. An echoprint of the input, including a plot of the rightside geometry, is shown in Figure 74, with the equilibrium analysis results given in Figure 75. Frame model data and plots of the frame model are shown in Figure 76, and results of the frame analysis are given in Figure 77.

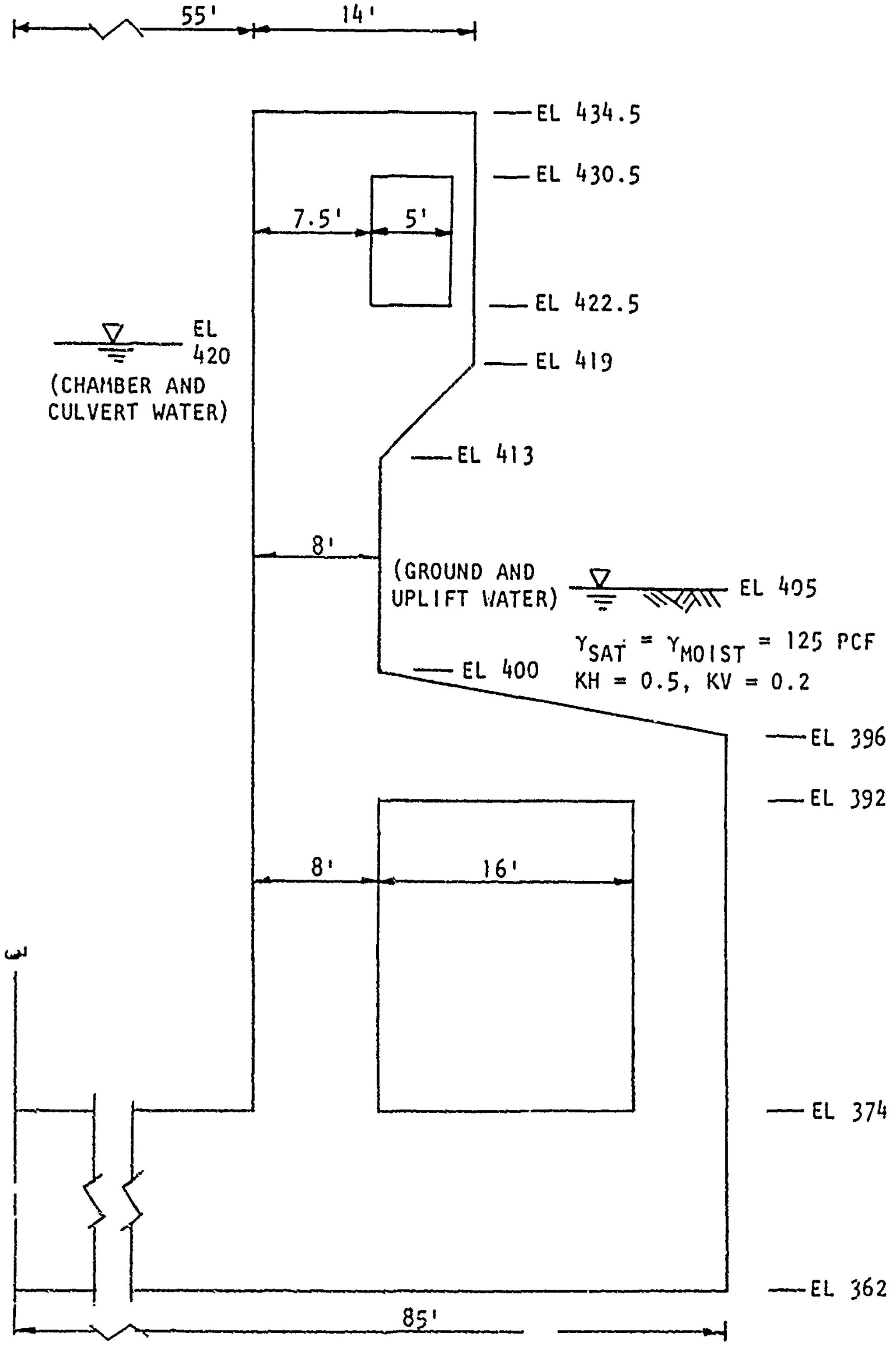


Figure 68. System for Example 4

***** INPUT FILE FOR EXAMPLE 4 *****

```
1000 'EXAMPLE 4 - NONCONFORMING MONOLITH
1010 METHOD  EQ
1020 STRUCTURE    3.00E+06        .20     150.00       1.00
1030 FLOOR            55.00     374.00        .00
1040 BASE  BOTH                  85.00     362.00
1050 STEM  BOTH           5
1060      14.00     434.50       14.00     419.00       8.00     413.00
1070       8.00     400.00       30.00     396.00
1080 CULVERT  BOTH                8.00      16.00     374.00      18.00         .00
1090 VOIDS  BOTH                  7.50       5.00     422.50       8.00           0
1100 BACKFILL  BOTH      SOIL        1        .00
1110     405.00     125.00     125.00        .50        .50        .20         .20
1120 REACTION SOIL TRAPEZOIDAL                .50
1130 WATER            62.5
1140 EXTERNAL  BOTH      ELEVATION      405.00
1150 UPLIFT ELEVATION          405.00     405.00
1160 INTERNAL        420.00     420.00     420.00
1170 FINISH
```

Figure 69. Input file for Example 4

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89                                                TIME: 12:10:36

I.--HEADING
  'EXAMPLE 4 - NONCONFORMING MONOLITH

               ****************
               *  INPUT DATA  *
               ****************


II.--EQUILIBRIUM ANALYSIS ONLY

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =     .20
     UNIT WEIGHT OF CONCRETE            =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    1.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      55.00 (FT)
     FLOOR ELEVATION   =     374.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CENTERLINE      ELEVATION
         (FT)           (FT)
         85.00         362.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE      ELEVATION
         (FT)           (FT)
         14.00         434.50
         14.00         419.00
          8.00         413.00
          8.00         400.00
         30.00         396.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

Figure 70. Echoprint of input data for Example 4 (Continued)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00 (FT)
CULVERT WIDTH	=	16.00 (FT)
ELEVATION AT CULVERT FLOOR	=	374.00 (FT)
CULVERT HEIGHT	=	18.00 (FT)
CULVERT FILLET SIZE	=	0.00 (FT)

III.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA

III.F.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	7.50 (FT)
VOID WIDTH	=	5.00 (FT)
ELEVATION AT VOID BOTTOM	=	422.50 (FT)
VOID HEIGHT	=	8.00 (FT)
VOID TIES		NONE

III.F.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
405.00	125.0	125.0	.500	.500	.200	.200

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

REACTION PROVIDED BY TRAPEZOIDAL SOIL PRESSURE DISTRIBUTION
FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE = .50

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 405.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 405.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 405.00 (FT)

VI.C.--INTERNAL WATER DATA

WATER ELEVATION IN CHAMBER	=	420.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT	=	420.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT	=	420.00 (FT)

VII.--ADDITIONAL LOAD DATA
NONE

Figure 70. (Concluded)

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89                                                  TIME: 12:11:03

I.--HEADING
  'EXAMPLE 4 - NONCONFORMING MONOLITH


    ************************************
    *  RESULTS OF EQUILIBRIUM ANALYSIS  *
    ************************************


 II.--EFFECTS ON STRUCTURE RIGHTSIDE


   II.A.--PRESSURES ON RIGHTSIDE SURFACE
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
     (POSITIVE SHEAR IS DOWN)
     (UNITS ARE POUNDS AND FEET)

                 <--------BACKFILL PRESSURE--------->       GRND/SURCH
     ELEVATION    VERTICAL     HORIZONTAL      SHEAR        WATER PRESSURE
       434.500    0.           0.              0.             0.
       430.500    0.           0.              0.             0.
       422.500    0.           0.              0.             0.
       420.000    0.           0.              0.             0.
       419.000    0.           0.              0.             0.
       413.000    0.           0.              0.             0.
       405.000    0.           0.              0.             0.
       400.000    3.1250E+02   1.5625E+02      6.2500E+01     3.1250E+02
       396.000    5.6250E+02   2.8125E+02      1.1250E+02     5.6250E+02
       392.000    8.1250E+02   4.0625E+02      1.6250E+02     8.1250E+02
       374.000    1.9375E+03   9.6875E+02      3.8750E+02     1.9375E+03
       362.000    2.6875E+03   1.3438E+03      5.3750E+02     2.6875E+03


   II.B.--PRESSURE ON RIGHTSIDE BASE
     (POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

     DIST  FROM         SOIL REACTION         UPLIFT WATER
     CENTERLINE           PRESSURE              PRESSURE
        0.000            1.4750E+03            2.6875E+03
       55.000            3.3837E+03            2.6875E+03
       63.000            3.6614E+03            2.6875E+03
       79.000            4.2167E+03            2.6875E+03
       85.000            4.4249E+03            2.6875E+03
```

Figure 71. Results of equilibrium analysis for Example 4 (Continued)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	3.0816E+04	2.1181E+04	-1.5844E+06
GROUND/SURCH WATER	5.7781E+04	9.6250E+03	-5.8751E+05
INTERNAL WATER	-6.6125E+04	1.7613E+05	-6.6404E+06
UPLIFT WATER	0.	-2.2844E+05	9.7086E+06
SOIL BASE REACT	0.	-2.5074E+05	1.2433E+07
CONCRETE	0.	2.7225E+05	-1.4262E+07
TOTAL THIS SIDE	2.2472E+04	0.	-9.3251E+05

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

V.--CONCRETE AREAS
RIGHTSIDE AREA = 1.8150E+03 (SQFT)
LEFTSIDE AREA = 1.8150E+03 (SQFT)
TOTAL AREA = 3.6300E+03 (SQFT)

Figure 71. (Concluded)

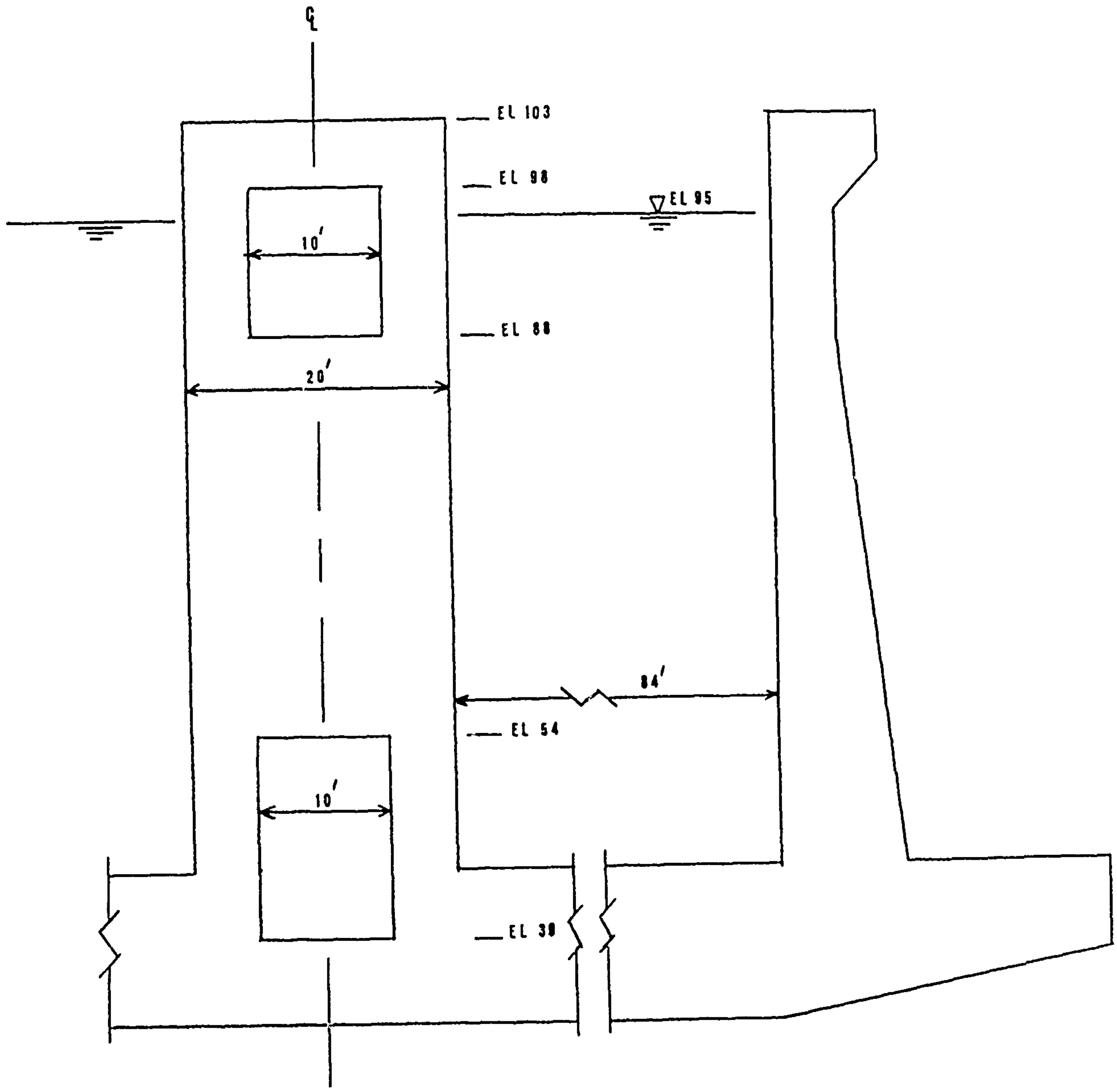


Figure 72. System for Example 5

***** INPUT FILE FOR EXAMPLE 5 *****

```
1000  'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
1010  'SYMMETRIC SOIL-FOUNDED STRUCTURE
1020 METHOD  FR          .75        1.00
1030 STRUCTURE    3.00E+06          .20      150.00       1.00
1040 FLOOR           94.00        44.00         .00
1050 BASE  BOTH                   94.00       32.00     120.00      37.00
1060 STEM  BOTH          6
1070        8.50    103.00         8.50       99.00       5.00      95.00
1080        5.00     85.00        10.00       44.00      26.00      44.00
1090 STEM CENTER                  20.00      103.00
1100 CULVERT CENTER      1        10.00       39.00      15.00
1110 VOID CENTER                  10.00       88.00      10.00          0
1120 BACKFILL  BOTH      SOIL         1         .00
1130       76.00    130.00       130.00         .50        .50        .00        .00
1140 REACTION SOIL UNIFORM
1150 WATER           62.5
1160 EXTERNAL  BOTH      ELEVATION            64.00
1170 UPLIFT ELEVATION             64.00       64.00
1180 INTERNAL BOTH                95.00
1190 FINISH
```

Figure 73. Input file for Example 5

```
PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89                                                TIME: 12:38:48

I.--HEADING
  'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
  'SYMMETRIC SOIL-FOUNDED STRUCTURE

               ****************
               *  INPUT DATA  *
               ****************


II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR   =          .75
     MEMBER FORCE FACTOR =         1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =      .20
     UNIT WEIGHT OF CONCRETE            =   150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =     1.00    (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      94.00 (FT)
     FLOOR ELEVATION   =      44.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CENTERLINE      ELEVATION
         (FT)            (FT)
         94.00          32.00
        120.00          37.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

a. Echoprint (Continued)

Figure 74. Input data for Example 5 (Sheet 1 of 4)

III.D.--STEM DATA

III.D.1.--RIGHTSIDE

DISTANCE FROM STEM FACE (FT)	ELEVATION (FT)
8.50	103.00
8.50	99.00
5.00	95.00
5.00	85.00
10.00	44.00
26.00	44.00

III.D.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.D.3.--CENTER
STEM WIDTH = 20.00 (FT)
STEM ELEVATION = 103.00 (FT)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE
NONE

III.E.2.--LEFTSIDE
NONE

III.E.3.--CENTER (ONE CULVERT)
CULVERT WIDTH = 10.00 (FT)
ELEVATION AT CULVERT FLOOR = 39.00 (FT)
CULVERT HEIGHT = 15.00 (FT)

III.F.--VOID DATA

III.F.1.--RIGHTSIDE
NONE

III.F.2.--LEFTSIDE
NONE

III.F.3.--CENTER
VOID WIDTH = 10.00 (FT)
ELEVATION AT VOID BOTTOM = 88.00 (FT)
VOID HEIGHT = 10.00 (FT)
VOID TIES NONE

a. (Continued)

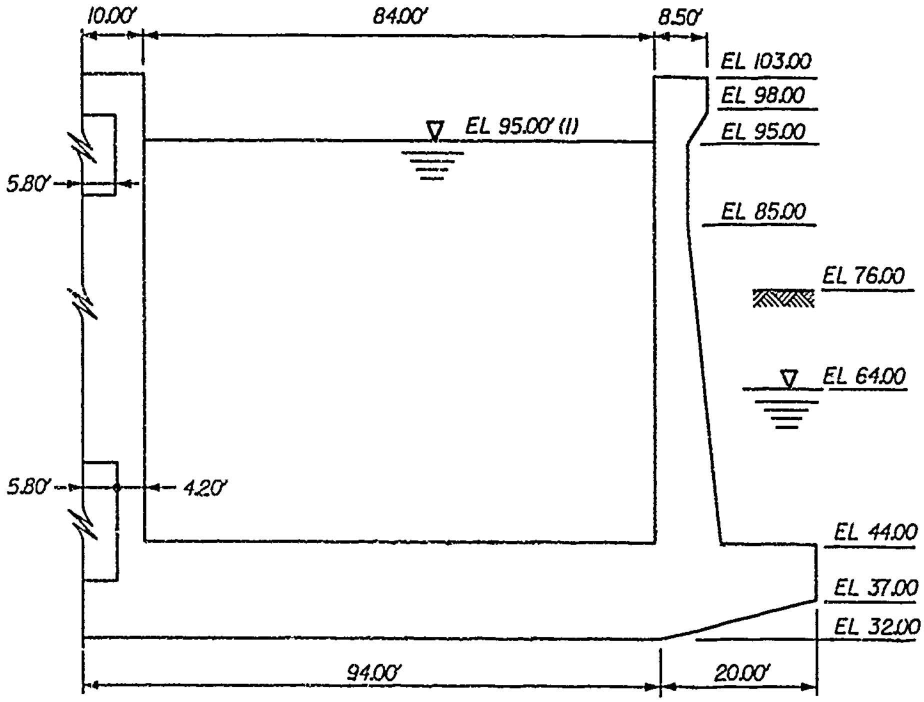
Figure 74. (Sheet 2 of 4)

```
IV.--BACKFILL DATA

  IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE =      0.00 (PSF))
     ELEV                                   <-PRESSURE COEFFICIENTS->
      AT     SATURATED      MOIST         HORIZONTAL          SHEAR
     TOP      UNIT WT.    UNIT WT.      TOP     BOT.       TOP    BOT.
     (FT)      (PCF)        (PCF)
     76.00      130.0        130.0       .500    .500      0.000 0.000

  IV.B.--LEFTSIDE SOIL LAYER DATA
     SYMMETRIC WITH RIGHTSIDE


V.--BASE REACTION DATA

     REACTION PROVIDED BY UNIFORM     SOIL PRESSURE DISTRIBUTION

VI.--WATER DATA
     WATER UNIT WEIGHT =  62.5 (PCF)

  VI.A.--EXTERNAL WATER DATA

    VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
     GROUND WATER ELEVATION     =      64.00 (FT)
     SURCHARGE WATER                    NONE

    VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
     SYMMETRIC WITH RIGHTSIDE

  VI.B.--UPLIFT WATER DATA
     RIGHTSIDE UPLIFT WATER ELEVATION =      64.00 (FT)
     LEFTSIDE UPLIFT WATER ELEVATION  =      64.00 (FT)

  VI.C.--INTERNAL WATER DATA

    VI.C.1.--RIGHTSIDE
     WATER ELEVATION IN CHAMBER =     95.00 (FT)

    VI.C.2.--LEFTSIDE
     WATER ELEVATION IN CHAMBER =     95.00 (FT)

    VI.C.3.--CENTER
     WATER ELEVATION IN CULVERT =      0.00 (FT)

VII.--ADDITIONAL LOAD DATA
     NONE
```

a. (Concluded)

Figure 74 (Sheet 3 of 4)

EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5
MONOLITH SYMMERTRIC SOIL-FOUNDED STRUCTURE



(1) CHAMBER

RIGHTSIDE

b. Plot of input geometry

Figure 74. (Sheet 4 of 4)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89 TIME: 12:39:13

I.--HEADING
'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

```
*************************************
*  RESULTS OF EQUILIBRIUM ANALYSIS  *
*************************************
```

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
103.000	0.	0.	0.	0.
99.000	0.	0.	0.	0.
95.000	0.	0.	0.	0.
85.000	0.	0.	0.	0.
76.000	0.	0.	0.	0.
64.000	1.5600E+03	7.8000E+02	0.	0.
44.000	2.9100E+03	1.4550E+03	0.	1.2500E+03
44.000	2.9100E+03	1.4550E+03	0.	1.2500E+03
37.000	3.3825E+03	1.6913E+03	0.	1.6875E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CENTERLINE	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	3.7105E+03	2.0000E+03
94.000	3.7105E+03	2.0000E+03
120.000	3.7105E+03	1.6875E+03

Figure 75. Equilibrium analysis for Example 5 (Continued)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE

(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	3.8042E+04	5.3153E+04	-5.6172E+06
GROUND/SURCH WATER	2.2781E+04	2.1524E+04	-2.3517E+06
INTERNAL WATER	0.	2.6775E+05	-1.3923E+07
UPLIFT WATER	9.2187E+03	-2.3594E+05	1.3859E+07
SOIL BASE REACT	0.	-4.4526E+05	2.6716E+07
BACKFILL ON BASE	8.8781E+03	0.	-8.4694E+04
CONCRETE	0.	3.3878E+05	-1.8405E+07
TOTAL THIS SIDE	7.8920E+04	0.	1.9395E+05

III.--EFFECTS ON STRUCTURE LEFTSIDE

SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS

(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CENTERLINE)
(UNITS ARE POUNDS AND FEET)

TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

V.--CONCRETE AREAS

RIGHTSIDE AREA = 2.2585E+03 (SQFT)
LEFTSIDE AREA = 2.2585E+03 (SQFT)
TOTAL AREA = 4.5170E+03 (SQFT)

Figure 75. (Concluded)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89 TIME: 12:39:27

I.--HEADING
'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* FRAME MODEL DATA *
****

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 1 MONOLITH
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

		<---------------	------	------CORNER	LOCATIONS------	------	--------------->	
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	94.00	94.00	104.00	104.00	104.00	94.00	98.85
	ELEVATION	32.00	44.00	44.00	44.00	33.92	32.00	38.47
6	X-COORD.	94.00	94.00	102.50	102.50	99.00	99.00	97.90
	ELEVATION	95.00	103.00	103.00	99.00	95.00	95.00	99.31

II.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	38.00000
2	98.85482	38.46681
3	120.00000	40.50000
4	96.50000	85.00000
5	97.89617	99.30601

II.C.--MEMBER DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	10.00	38.00	95.21	38.00	12.00	12.00
2	2	3	102.71	38.84	120.00	40.50	10.08	7.00
3	2	4	99.08	42.62	96.50	85.00	10.00	5.00
4	4	5	96.50	85.00	96.50	96.08	5.00	5.00

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

a. Model data (Continued)

Figure 76. Plane frame model for Example 5 (Sheet 1 of 5)

IV.--CENTER STEM MODEL DATA - TYPE C5 MONOLITH

IV.A.--RIGID BLOCK DATA (FT)
(NOTE: "X-COORD." IS DISTANCE FROM STRUCTURE CENTERLINE; + TO RIGHT, - TO LEFT.)

BLOCK 1:

CORNER NO.	X-COORD.	ELEVATION
1	-10.00	32.00
2	-10.00	44.00
3	-5.00	44.00
4	-5.00	39.00
5	5.00	39.00
6	5.00	44.00
7	10.00	44.00
8	10.00	32.00
CENTROID	0.00	38.00

BLOCK 2:

CORNER NO.	X-COORD.	ELEVATION
1	5.00	54.00
2	5.00	88.00
3	5.00	88.00
4	10.00	88.00
5	10.00	54.00
CENTROID	7.50	71.00

BLOCK 3:

CORNER NO.	X-COORD.	ELEVATION
1	-10.00	54.00
2	-10.00	88.00
3	-5.00	88.00
4	-5.00	88.00
5	-5.00	54.00
CENTROID	-7.50	71.00

BLOCK 4:

CORNER NO.	X-COORD.	ELEVATION
1	5.00	98.00
2	5.00	103.00
3	10.00	103.00
4	10.00	98.00
CENTROID	7.50	100.50

BLOCK 5:

CORNER NO.	X-COORD	ELEVATION
1	-10.00	98.00
2	-10.00	103.00
3	-5.00	103.00
4	-5.00	98.00
CENTROID	-7.50	100.50

a. (Continued)

Figure 76. (Sheet 2 of 5)

IV.B.--JOINT COORDINATES (FT)
(NOTE: "X-COORD." IS DISTANCE FROM STRUCTURE CENTERLINE.)

IV.B.1.--RIGHTSIDE JOINTS

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	38.00000
2	7.50000	71.00000
3	7.50000	100.50000

IV.B.2.--LEFTSIDE JOINTS
SYMMETRIC WITH RIGHTSIDE

IV.C.--MEMBER DATA (FT)
(NOTE: "XCOORD." IS DISTANCE FROM STRUCTURE CENTERLINE.)

IV.C.1.--RIGHTSIDE MEMBERS

			<COORDS AT ENDS OF FLEX LENGTH>				
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->
NO	JT	JT	X	ELEV	X	ELEV	
1	1	2	7.50	44.00	7.50	54.00	5.00
2	2	3	7.50	88.00	7.50	98.00	5.00

IV.C.2.--LEFTSIDE MEMBERS
SYMMETRIC WITH RIGHTSIDE

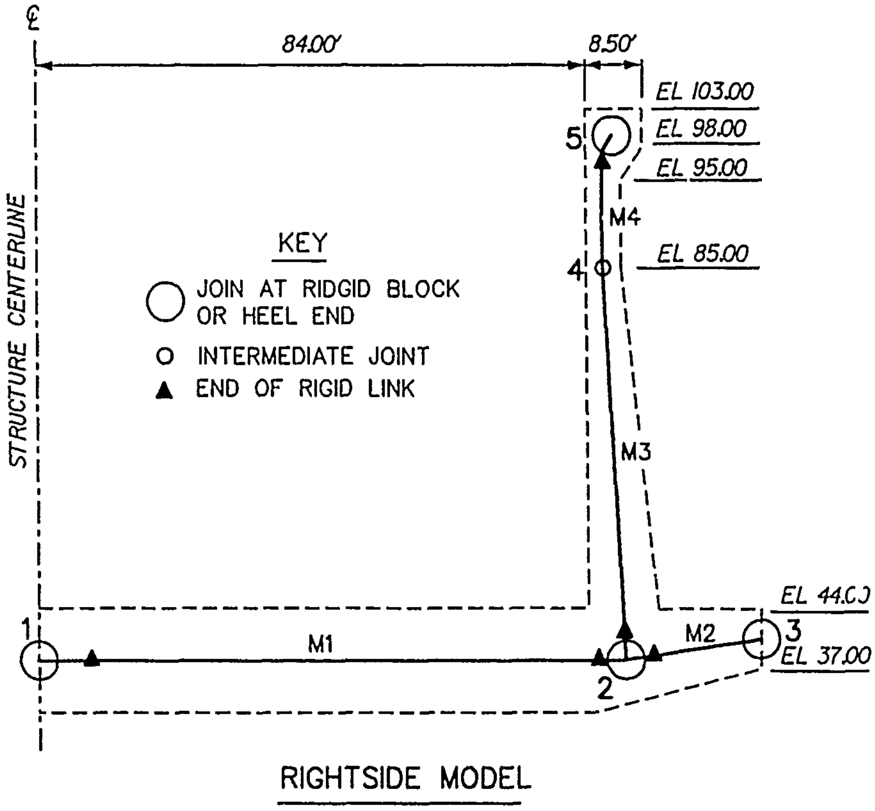
IV.C.3.--MEMBERS ON OR CROSSING STRUCTURE CENTERLINE

			<COORDS AT ENDS OF FLEX LENGTH>				
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->
NO	JT	JT	X	ELEV	X	ELEV	
2	L2	R2	-5.00	71.00	5.00	71.00	34.00
3	L3	R3	-5.00	100.50	5.00	100.50	5.00

a. (Concluded)

Figure 76. (Sheet 3 of 5)

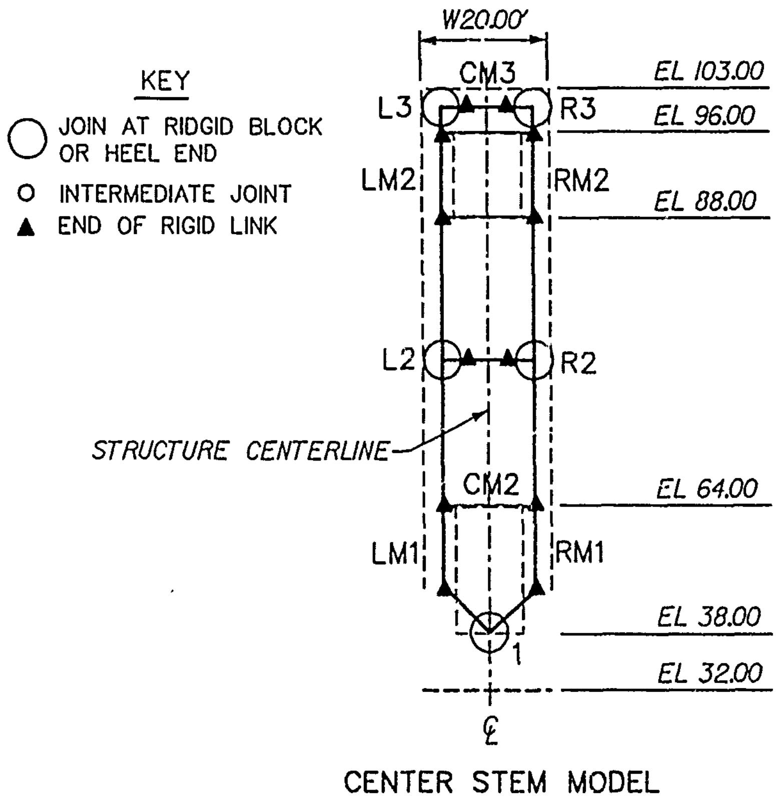
EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH SYMMERTRIC SOIL-FOUNDED STRUCTURE



b. Frame model plot (Continued)

Figure 76. (Sheet 4 of 5)

EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH SYMMERTRIC SOIL-FOUNDED STRUCTURE



b. (Concluded)

Figure 76. (Sheet 5 of 5)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89 TIME: 12:39:40

I.--HEADING
'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* RESULTS OF FRAME ANALYSIS *
****

II.--STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD STRUCTURE CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	38.00	0.	0.	0.
2	98.85	38.47	-1.151E-03	1.103E-01	-2.382E-03
3	120.00	40.50	-5.903E-03	1.607E-01	-2.382E-03
		***** STEM JOINTS *****			
4	96.50	85.00	-1.331E-01	1.037E-01	-3.070E-03
5	97.90	99.31	-1.773E-01	1.081E-01	-3.107E-03

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

II.C.--CENTER STEM DISPLACEMENTS - TYPE C5 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TO THE RIGHT.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

II.C.1.--RIGHTSIDE CENTER STEM JOINTS

JT NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
1	0.00	38.00	0.	0.	0.
2	7.50	71.00	2.282E-05	8.681E-05	2.872E-06
3	7.50	100.50	-4.469E-06	1.389E-04	2.268E-06

II.C.2.-- LEFTSIDE CENTER STEM JOINTS

SYMMETRIC WITH RIGHTSIDE

Figure 77. Results of frame analysis for Example 5 (Sheet 1 of 4)

III.--UNFACTORED FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 1 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD STRUCTURE CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD STRUCTURE CENTERLINE.)

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	10.00	38.00	-2.361E+03	-3.064E+04	-1.308E+06
	95.21	38.00	-2.361E+03	-3.009E+04	-1.295E+06
2	102.71	38.84	3.192E+04	-3.928E+03	9.450E+03
	120.00	40.50	2.120E+04	2.038E+03	-2.751E+03
		***** STEM MEMBERS *****			
3	89.08	42.62	7.330E+04	3.736E+04	-9.868E+05
	96.50	85.00	1.681E+04	-2.106E+03	-2.319E+04
4	96.50	85.00	1.665E+04	3.125E+03	-2.319E+04
	96.50	96.08	9.150E+03	0.	-1.277E+04

III.B.-- LEFTSIDE MEMBERS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

III.C.--CENTER STEM MEMBERS - TYPE C5 MONOLITH

III.C.1.--RIGHTSIDE CENTER STEM MEMBERS

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
1	0.00	0.00	2.250E+04	-1.230E+04	1.227E+04
	0.00	0.00	1.500E+04	-1.645E+04	3.823E+04
2	-5.00	71.00	1.500E+04	3.994E+02	-6.977E+03
	5.00	71.00	7.500E+03	-1.931E+03	8.757E+03

III.C.2.-- LEFTSIDE CENTER STEM MEMBERS

SYMMETRIC WITH RIGHTSIDE

III.C.3.--MEMBERS ON OR CROSSING STRUCTURE CENTERLINE
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TO THE LEFT.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON LEFTSIDE OF MEMBER.)

MEM NO	DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
2	-5.00	71.00	6.705E+04	-2.550E+04	-8.551E+05
	5.00	71.00	6.705E+04	-2.550E+04	-8.551E+05
3	-5.00	100.50	1.931E+03	3.750E+03	-4.208E+03
	5.00	100.50	1.931E+03	3.750E+03	-4.208E+03

Figure 77. (Sheet 2 of 4)

PROGRAM CWFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME OR W-FRAME STRUCTURES
DATE: 07/11/89 TIME: 12:39:47

I.--HEADING
'EXAMPLE 5 - TYPE 1 MONOLITH COMBINED WITH A C5 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

II.--RIGHTSIDE CULVERT WALL
TYPE C5 MONOLITH

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION TOWARD THE STRUCTURE CENTERLINE.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE SIDE OF THE MEMBER TOWARD THE STRUCTURE CENTERLINE.)

II.A.--UNFACTORED MEMBER FORCES

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
7.50	44.00	2.250E+04	-1.230E+04	1.227E+04
7.50	45.00	2.175E+04	-9.144E+03	1.555E+03
7.50	46.00	2.100E+04	-6.050E+03	-6.037E+03
7.50	47.00	2.025E+04	-3.019E+03	-1.057E+04
7.50	48.00	1.950E+04	-5.006E+01	-1.210E+04
7.50	49.00	1.875E+04	2.856E+03	-1.069E+04
7.50	50.00	1.800E+04	5.700E+03	-6.404E+03
7.50	51.00	1.725E+04	8.481E+03	6.921E+02
7.50	52.00	1.650E+04	1.120E+04	1.054E+04
7.50	53.00	1.575E+04	1.386E+04	2.307E+04
7.50	54.00	1.500E+04	1.645E+04	3.823E+04

III.--RIGHTSIDE VOID WALL
TYPE C5 MONOLITH

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION TOWARD THE STRUCTURE CENTERLINE.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE SIDE OF THE MEMBER TOWARD THE STRUCTURE CENTERLINE.)

III.A.--UNFACTORED MEMBER FORCES

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
7.50	88.00	1.500E+04	3.994E+02	-6.977E+03
7.50	89.00	1.425E+04	8.057E+02	-6.369E+03
7.50	90.00	1.350E+04	1.149E+03	-5.387E+03
7.50	91.00	1.275E+04	1.431E+03	-4.091E+03
7.50	92.00	1.200E+04	1.649E+03	-2.546E+03
7.50	93.00	1.125E+04	1.806E+03	-8.133E+02
7.50	94.00	1.050E+04	1.899E+03	1.044E+03
7.50	95.00	9.750E+03	1.931E+03	2.965E+03
7.50	96.00	9.000E+03	1.931E+03	4.895E+03
7.50	97.00	8.250E+03	1.931E+03	6.826E+03
7.50	98.00	7.500E+03	1.931E+03	8.757E+03

Figure 77. (Sheet 3 of 4)

IV.-- LEFTSIDE CULVERT WALL
SYMMETRIC WITH RIGHTSIDE

V.-- LEFTSIDE VOID WALL
SYMMETRIC WITH RIGHTSIDE

VI.--WALL BETWEEN CULVERTS
NOT PRESENT

VII.--MEMBER BETWEEN CULVERT AND VOID
TYPE C5 MONOLITH

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION UPWARD.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE TOP OF THE MEMBER.)

VII.A.--UNFACTORED MEMBER FORCES

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
5.00	71.00	6.705E+04	-2.550E+04	-3.551E+05
4.00	71.00	6.705E+04	-2.040E+04	-8.322E+05
3.00	71.00	6.705E+04	-1.530E+04	-8.143E+05
2.00	71.00	6.705E+04	-1.020E+04	-8.016E+05
1.00	71.00	6.705E+04	-5.100E+03	-7.939E+05
0.00	71.00	6.705E+04	3.376E-09	-7.914E+05
-1.00	71.00	6.705E+04	5.100E+03	-7.939E+05
-2.00	71.00	6.705E+04	1.020E+04	-8.016E+05
-3.00	71.00	6.705E+04	1.530E+04	-8.143E+05
-4.00	71.00	6.705E+04	2.040E+04	-8.322E+05
-5.00	71.00	6.705E+04	2.550E+04	-8.551E+05

VIII.--VOID ROOF
TYPE C5 MONOLITH

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION UPWARD.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE TOP OF THE MEMBER.)

VIII.A.--UNFACTORED MEMBER FORCES

DISTANCE FROM CTR-LINE (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
5.00	100.50	1.931E+03	3.750E+03	-4.208E+03
6.00	100.50	1.931E+03	3.000E+03	-8.334E+02
7.00	100.50	1.931E+03	2.250E+03	1.792E+03
8.00	100.50	1.931E+03	1.500E+03	3.667E+03
9.00	100.50	1.931E+03	7.500E+02	4.792E+03
10.00	100.50	1.931E+03	1.164E-10	5.167E+03
11.00	100.50	1.931E+03	-7.500E+02	4.792E+03
12.00	100.50	1.931E+03	-1.500E+03	3.667E+03
13.00	100.50	1.931E+03	-2.250E+03	1.792E+03
14.00	100.50	1.931E+03	-3.000E+03	-8.334E+02
15.00	100.50	1.931E+03	-3.750E+03	-4.208E+03

Figure 77. (Sheet 4 of 4)

APPENDIX A: GUIDE FOR DATA INPUT

Source of Input

1. Input data may be supplied from a predefined data file or from the user terminal during execution. If data are supplied from the user terminal, prompting messages are printed to indicate the amount and character of data to be entered.

Data Editing

2. When all data for a problem have been entered, the user is offered the opportunity to review an echoprint of the currently available input data and to revise any or all sections of the input data before execution is attempted. When data are edited during execution, each section must be entered in its entirety.

Input Data File Generation

3. After data have been entered from the terminal, initially or after editing, the user may direct the program to write the input data to a permanent file in input data file format.

Data Format

4. All input data (supplied from the user terminal or from a file) are read in free-field format:

   a. Data items must be separated by one or more blanks (comma separators are not permitted).

   b. Integer numbers must be of the form NNNN.

   c. Real numbers may be of form.

      +xxxx, +xx.xx, or +xx.xxE+ee

   d. User responses to all requests for control by the program for alphanumeric input may be abbreviated by the first letter of the indicated word response, e.g.,

      ENTER 'YES' OR 'NO'--respond Y or N

      ENTER 'CONTINUE' OR 'END'--respond C or E

5. Input data are divided into the sections shown in Figure A1.

I. Heading (Required)

II. Control (Required)

III. Structural Data

A. Control (Required)

B. Floor Data (Required)

C. Stem Data (Required)

D. Culvert Data (Optional)

E. Void Data (Optional)

F. Center Stem Data (Optional)

G. Center Culvert Data (Optional)

H. Center Void Data (Optional)

IV. Backfill Data (Optional)

V. Base Reaction Data (Required)

VI. Water Data (Optional)

VII. Additional Load Data (Optional)

VIII. Termination (Required)

Figure A1. Sections of input data

6. When data are entered from the terminal, prompts indicate the data items to be provided.

Units

7. The program expects data to be provided in units of inches, feet, pounds, or kips as noted in the following guide. No provision is made for conversion of units by the program.

Predefined Data File

8. In addition to the general format requirements given in paragraph 4 of this appendix, the following pertain to a predefined data file and to the input data description beginning in paragraph 12.

a. Each line must commence with a nonzero, positive line number denoted LN below.

b. A line of input may require both alphanumeric and numeric data items. Alphanumeric data items are enclosed in single quotes in the following paragraphs.

c. A line of input may require a keyword. The acceptable abbreviation for the keyboard is indicated by underlined capital letters, e.g., the acceptable abbreviation for the keyword 'PROperties' is 'PRO'.

d. Lower case words in single quotes indicate definitions of a choice of keywords will follow.

e. Items designated by upper case letters and numbers without quotes indicate numeric data values. Numeric data values are real or integer, according to standard FORTRAN variable naming conventions.

f. Data items enclosed in brackets [ ] may not be required. Data items enclosed in braces { } indicate special note follows.

g. Input data are divided into the sections discussed in paragraph 5. Except for the heading, each section consists of a header line and one or more data lines.

h. Comment lines may be inserted in the input file by enclosing the line, following the line number, in parentheses. Comment lines are ignored, e.g.,

1234 (THIS LINE IS IGNORED)

Sequence of Solutions

9. A predefined data file may contain a sequence of input data sets to be run in succession. Each data set must contain all required data (from heading through termination) for the problem and be independent of all other problems in the sequence. All output data for a sequence of problems are directed to a permanent file which must be retrieved after termination of execution. Data editing during execution is not available when a sequence of solutions is run.

General Discussion of Input Data

10. Each data section contains a descriptor {'side'} to indicate the side of the structure to which the data apply. For symmetric effects ('side' = 'Both'), the data section is entered only once and symmetric data are applied to both sides automatically. For unsymmetric conditions, except for

pile data, the description for the rightside* (if present) must be entered first and must be immediately followed by the description for the leftside* (if present). In the case of pile data, all pile data subsections must be entered for the rightside first, followed by all pile data subsections for the leftside.

11. Rightside and leftside descriptions must be supplied explicitly or implicitly (i.e., 'side' = 'Both') for STRUCTURE and BASE REACTION data sections. All other data may be supplied for the rightside or leftside, both sides, or may be omitted.

Input Description

12. CONTROL--Two (2) to five (5) lines

a. Heading--One (1) to four (4) lines

(1) Line contents

LN {'heading'}

(2) Definition

'heading' = any alphanumeric information up to 70 characters including LN and any embedded blanks. First nonblank character following LN must be a single quote (').

b. Method--One (1) line

(1) Line contents

LN 'Method' {'mode'} [RLF]

(2) Definitions

'Method' = keyword

'mode' = 'Equilibrium' if only pressure and resultant force evaluation required.

= 'Frame' if equilibrium analysis and 2-D plane frame analysis required.

[RLF] = rigid block reduction factor for member flexible lengths ($0 \leq RLF \leq 1$). Omit if 'mode' = 'Equilibrium'.

(3) Discussion

For 'mode' = 'Frame', the structure geometry must conform to one of the six types of monoliths described in Part V.

---

* The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the appendixes to be consistent with these terms as used in the computer programs in Appendix A.

13. STRUCTURE

a. Control--One (1) lir

(1) Line contents

LN 'Structure' EC PR WTCONC [SLICE]

(2) Definitions

'Structure' = keyword

EC = modulus of elasticity of concrete (PSI)

PR = Poisson's ratio for concrete (0 < PR < 0.5)

WTCONC = unit weight of concrete (PCF)

[SLICE] = thickness of slice of structure to be considered (FT); assumed to be one (1) ft if omitted

(3) Discussion

Any width of slice of structure to be analyzed may be used. If this item is omitted, a 1-ft slice is assumed. A slice width other than 1 ft may facilitate describing other effects (e.g., pile foundation) on the structure.

b. Floor data--One (1) line

(1) Line contents

LN 'Floor' FLRWID ELFLOR [FLRFIL]

(2) Definitions

'Floor' = keyword

FLRWID = distance from centerline* to inside face of outside stem (FT)

ELFLOR = elevation of chamber floor (FT)

[FLRFIL] = width of 45-deg fillet at floor-stem intersection (FT); assumed to be zero if omitted

(3) Discussion

(a) See Figure A2 for notation.

(b) All 'Floor' and 'Base' distances are measured from the centerline; i.e., from midpoint between interior stem faces of the outside stems.

(c) Identical 45-deg fillets are assumed to exist in both corners of the chamber floor.

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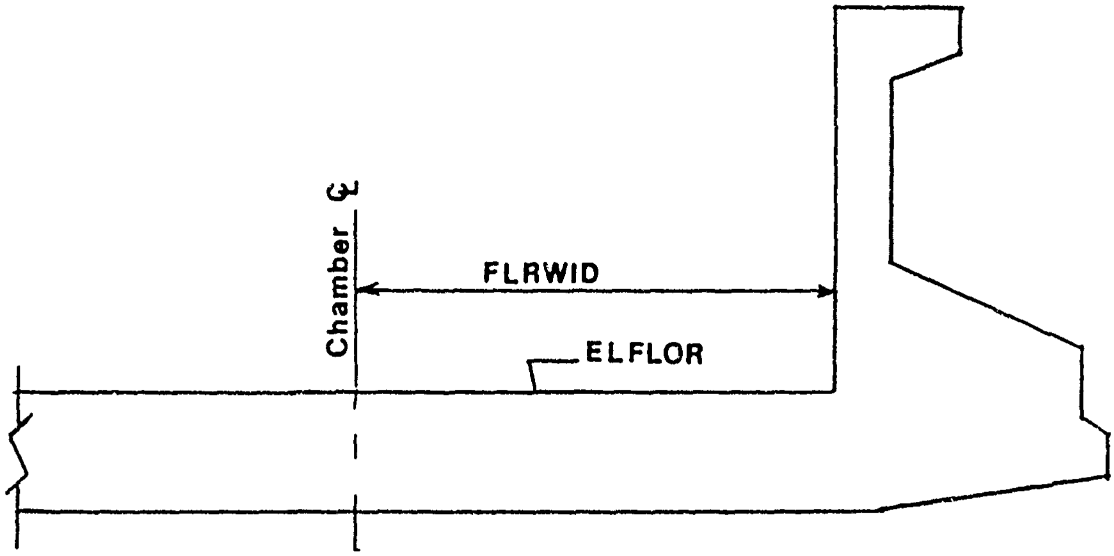
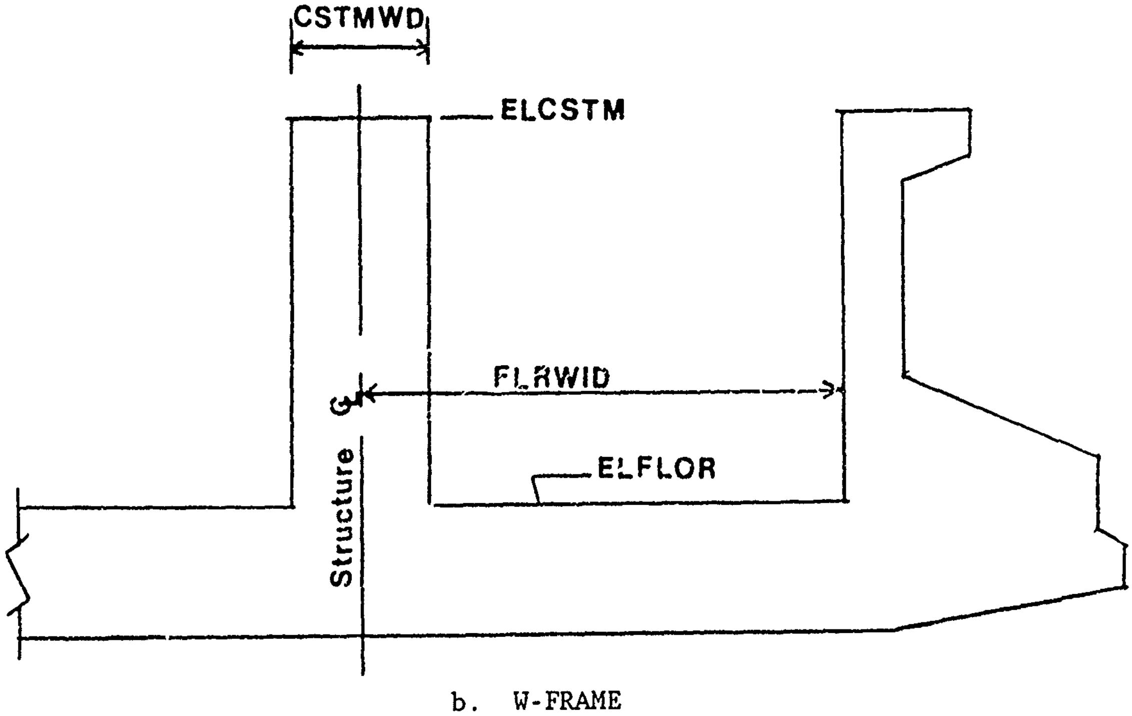
* Ibid.



a. U-FRAME



b. W-FRAME

Figure A2. U-FRAME and W-FRAME structures

c. Base data--One (1) or two (2) lines

(1) Line contents

LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]

(2) Definitions

'Base' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DBASE(1) = distance from chamber centerline to first base point (FT)

ELBASE(1) = elevation at base point (FT)

[DBASE(2), ELBASE(2)] = distance from centerline to second base point (FT) and the elevation (FT) at second base point; both may be omitted

(3) Discussion

(a) See Figure A3 for notation.

(b) Base points, define locations where changes in slope of the base occur. Up to two (2) points may be defined on either side of the centerline. The base is assumed to be horizontal from the centerline to the first point and is assumed to be straight between input points.

(c) If only one base point is provided, DBASE(1) must be greater than zero.

(d) If two points are provided, the following must be satisfied:

DBASE(1) $\geq$ 0

DBASE(2) > DBASE(1)

(e) Distances and elevations for some data items in subsequent sections are restricted by the base dimensions. For reference the limits are expressed in terms of DBASE(2) and ELBASE(2). If only one base point has been provided, DBASE(2) = DBASE(1) and ELBASE(2) = ELBASE(1).

(f) If {'side'} = 'Both', identical base point data are assigned to both sides of the structure base.

(g) If 'Rightside' and 'Leftside' base data differ, 'Rightside' ELBASE(1) must be equal to 'Leftside' ELBASE(1). Enter 'Rightside' base data first and immediately follow with 'Leftside' data.

d. Stem data--One (1) to four (4) lines

(1) Line contents

LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1) ...

[LN ... DSTEM(NPTS) ELSTEM(NPTS)]

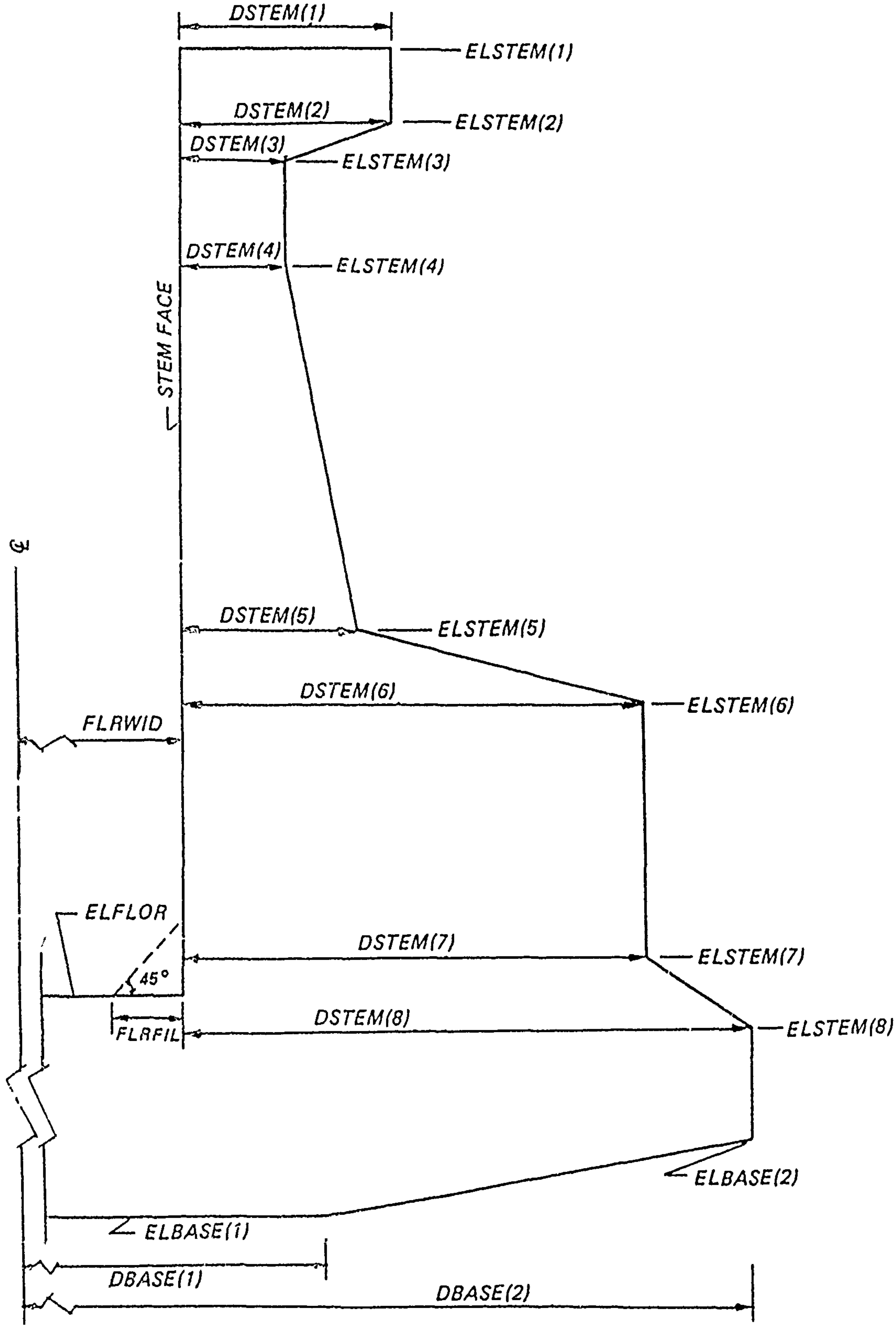


Figure A3. Outside stem and base

(Continue DSTEM, ELSTEM pairs on second line following line number until NPTS pairs provided)

(2) Definitions

'<u>S</u>tem' = keyword

{'side'} = '<u>R</u>ightside', '<u>L</u>eftside', or '<u>B</u>oth'

NPTS = number (1 to 8) of stem points

DSTEM(1) = distance from inside face of stem to i^{th} stem point (FT)

ELSTEM(1) = elevation at i^{th} stem point (FT)

(3) Discussion

(a) See Figure A3 for notation.

(b) If {'side'} = '<u>B</u>oth', identical stems are assumed.

(c) DSTEM, ELSTEM pairs must start at top of stem and proceed sequentially downward with:

$$DSTEM(1) > 0$$

$$ELSTEM(I) \leq ELSTEM(I - 1)$$

$$ELSTEM(NPTS) > ELBASE(2)$$

(d) The top of the stem is assumed to be horizontal at ELSTEM(1).

(e) Successive stem points are assumed to be connected by straight lines.

(f) The last stem point provided is connected by a straight line to the last base point provided.

(g) If 'mode' = '<u>F</u>rame', the number of stem points and locations of stem points must conform to limitations described in Part V.

(h) If '<u>R</u>ightside' and '<u>L</u>eftside' stem geometries differ, enter '<u>R</u>ightside' base data first and immediately follow with '<u>L</u>eftside' data.

<u>e</u>. Culvert data--Zero (0), one (1), or two (2) lines, entire section may be omitted

(1) Line contents

[LN '<u>C</u>ulvert' {'side'} DCUL CULWID ELCUL CULHGT [CULFIL]]

(2) Definitions

'<u>C</u>ulvert' = keyword

{'side'} = '<u>R</u>ightside', '<u>L</u>eftside', or '<u>B</u>oth'

DCUL = distance from inside stem face to interior vertical side of culvert (FT)

CULWID = width of the culvert opening (FT)

ELCUL = elevation of the floor of culvert (FT)

CULHGT = height of culvert opening (FT)

[CULFIL] = width of 45-deg fillet in the culvert corners (FT); assumed to be zero if omitted

(3) Discussion

(a) See Figure A4 for notation.

(b) If {'side'} = 'Both', identical culverts are assigned to both sides of the structure.

(c) If culvert data are provided for one side only, no culvert is assumed for the opposite side.

(d) A rectangular culvert is assumed. Culvert dimensions must result in the culvert opening lying entirely within the external boundaries defined by the stem and base data.

(e) Identical fillets are assumed in all four corners of the culvert except when stem void floor (see next section) coincides with the top of the culvert. In this case, fillets in the top corners are omitted.

(f) If different culverts occur on each side, enter 'Rightside' data first and immediately follow with 'Leftside' data.

(g) If 'mode' = 'Frame', culvert locations must conform to limitation described in Part V.

f. Stem void data--Zero (0) or one (1) to four (4) lines, entire section may be omitted

(1) Line 1 contents

[LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT [NTIES]]

(2) Line 2 contents (omit if NTIES = 0)

[LN ELTIE(1) HTIE(1) ELTIE(2) HTIE(2) ...

ELTIE(NTIES) HTIE(NTIES)]

(3) Definitions

'Void' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DVOID = distance from inside stem face to interior vertical side of void (FT)

VOIDWD = width of void opening (FT)

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

NTIES = number of horizontal structural members across opening (0 to 5)

ELTIE(I) = elevation at top of i^{th} tie member (FT)

HTIE(I) = depth of i^{th} tie member (FT)

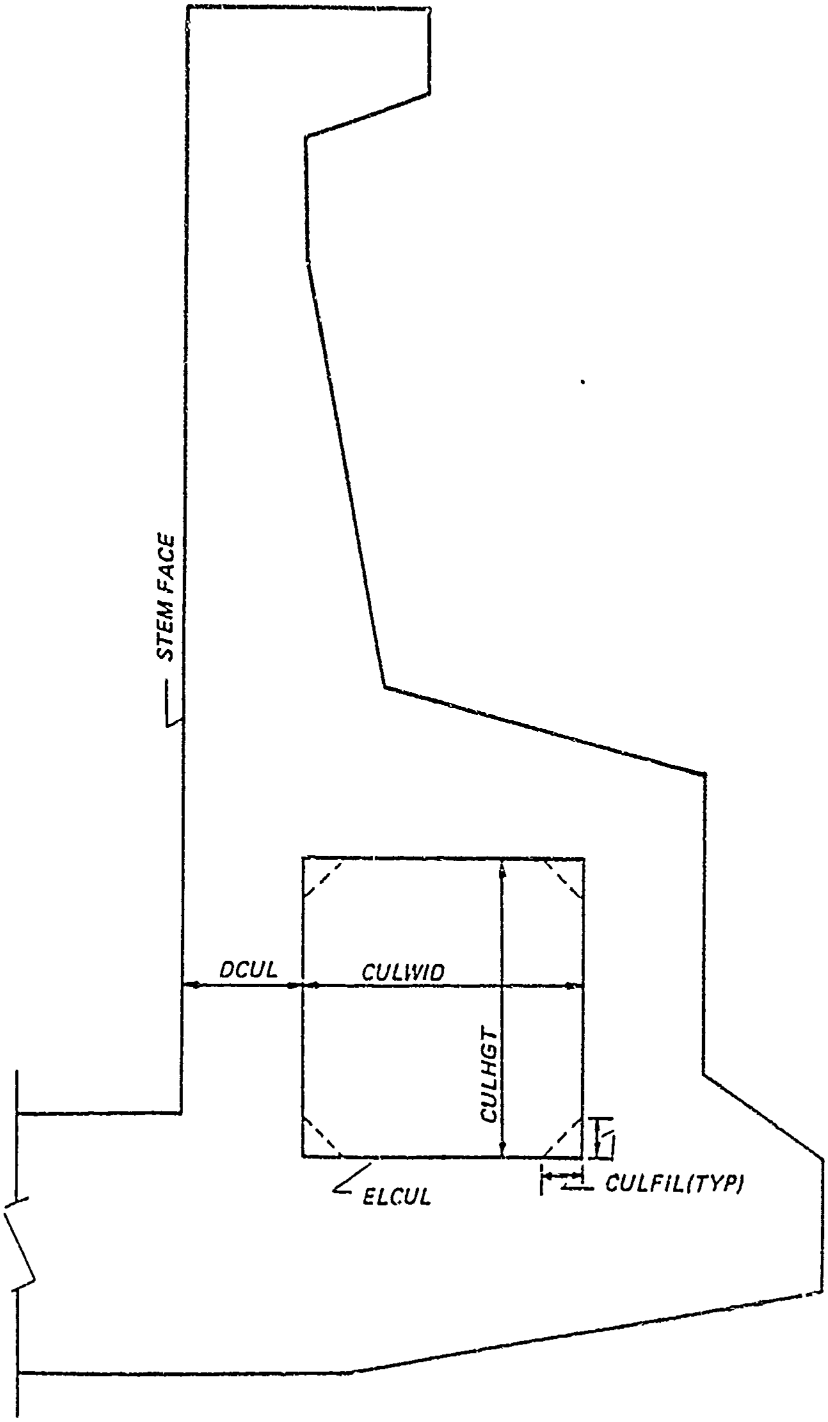


Figure A4. Outside stem culvert

(4) Discussion

(a) See Figure A5 for notation.

(b) If ('side') = 'Both', identical voids (and ties are assumed to exist in stems on both sides.

(c) If void (and tie) data are provided for one side only, no void is assumed in the opposite stem.

(d) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the stem and base data.

(e) Void data must satisfy the following:

ELVOID $\geq$ (ELCUL + CULHGT) if culvert present

(ELVOID + VOIDHT) $\leq$ ELSTEM(1)

(f) If ELVOID = (ELCUL + CULHGT), the top of the culvert is assumed to be open to the void and culvert fillets are omitted in the top corners of the culvert.

(g) If (ELVOID + VOIDHT) < ELSTEM(1), the void is treated as an additional rectangular opening in the stem.

(h) The void is assumed to be free of interior water unless the void is connected to the culvert.

(i) If 'mode' = 'Frame', a void may not exist in the stem unless the void is also present.

(j) Void ties are intended to provide a means of enforcing interaction between the vertical stem sections on either side of the void opening. The ties are considered to be fictitious concrete (but weightless) members with rectangular cross sections (HTIE X SLICE). They are assumed not to impede free communication of water though the void.

(k) Tie data must commence with the topmost tie and proceed sequentially downward.

(l) Restrictions on tie data are:

ELTIE(1) $\leq$ (ELVOID + VOIDHT)

ELTIE(I) $\leq$ (ELTIE(I-1) - HTIE(I - 1))

(ELTIE(NTIES) - HTIE(NTIES)) $\geq$ ELVOID

g. Center Stem--Zero (0) or one (1) line

(1) Line contents

[LN 'Stem Center' CSTMWD ELCSTM]

(2) Definitions

'Stem Center' = keyword

CSTMWD = width of center stem (FT)

ELCSTM = elevation of center stem (FT)

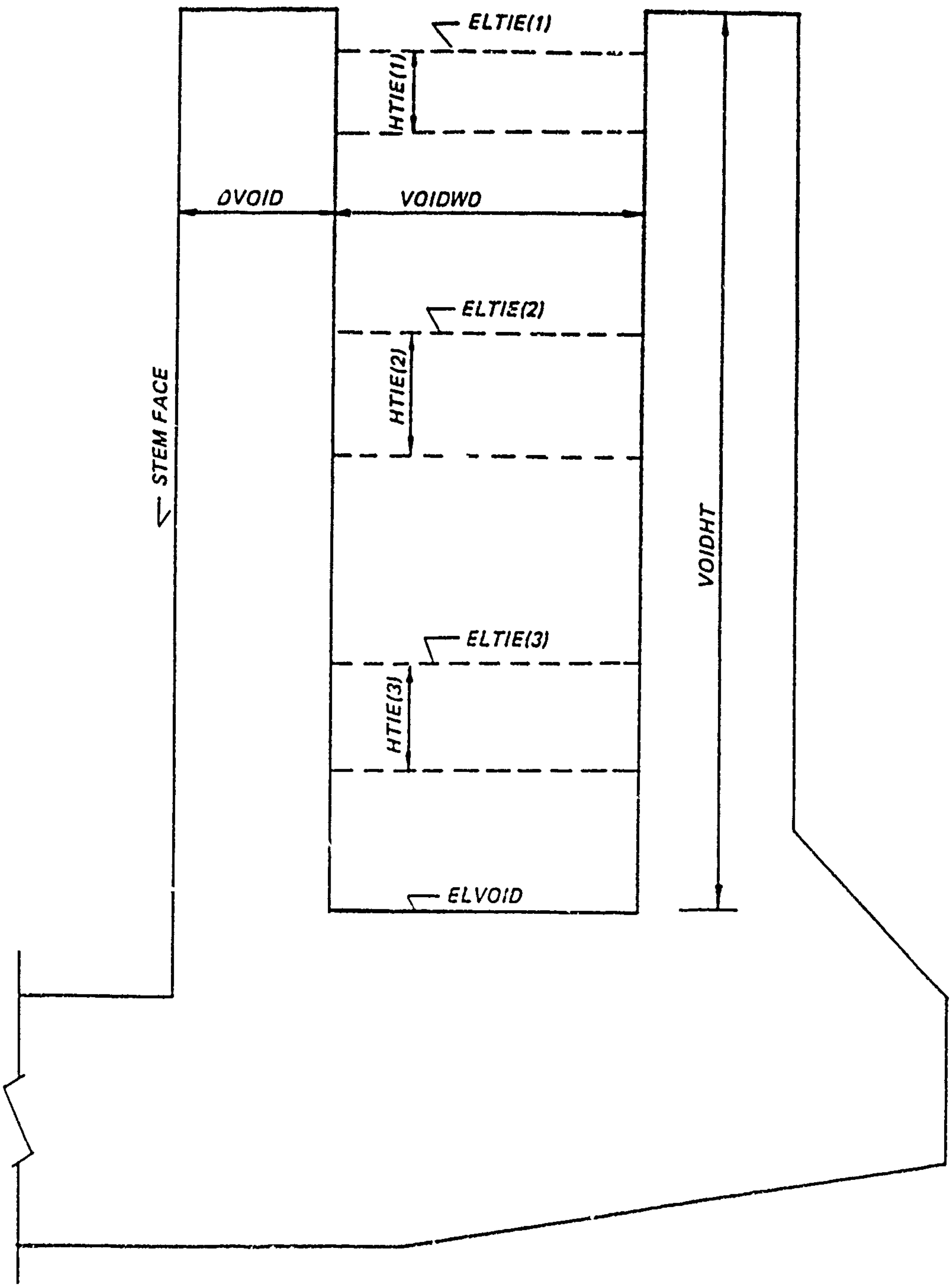


Figure A5. Outside stem void

(3) Discussion

(a) See Figures A2 and A6 for notation.

(b) Center stem including culvert(s) and void is symmetric about the structure centerline.

(c) Base data must satisfy the following:

DBASE(1) > CSTMWD/2

(d) If a center stem is present, two chambers of equal width and floor elevation are defined.

(e) Floor data must satisfy the following:

FLRWID > CSTMWD/2

ELFLOR < ELCSTM

h. Center Culvert--Zero (0) or one (1) line

(1) Line contents

[LN 'Culvert Center' NCUL CULWID ELCUL CULHGT [DCUL]]

(2) Definitions

'Culvert Center' = keyword

NCUL = number of culverts

CULWID = width of culvert(s) opening (FT)

ELCUL = elevation of floor of culvert(s) (FT)

CULHGT = height of culvert(s) opening (FT)

[DCUL] = distance between culverts (FT)

(3) Discussion

(a) See Figures A2 and A6 for notation.

(b) Rectangular culverts are assumed. Culvert dimensions must result in the culvert openings lying entirely within the external boundaries defined by center stem and base data.

(c) Center culvert data must satisfy the following:

ELCUL ≤ ELFLOR

i. Center Void--Zero (0) or one (1) to four (4) lines

(1) Line 1 contents

[LN 'Void Center' VOIDWD ELVOID VOIDHT [NTIES]]

(2) Line 2 contents (omit if NTIES = 0)

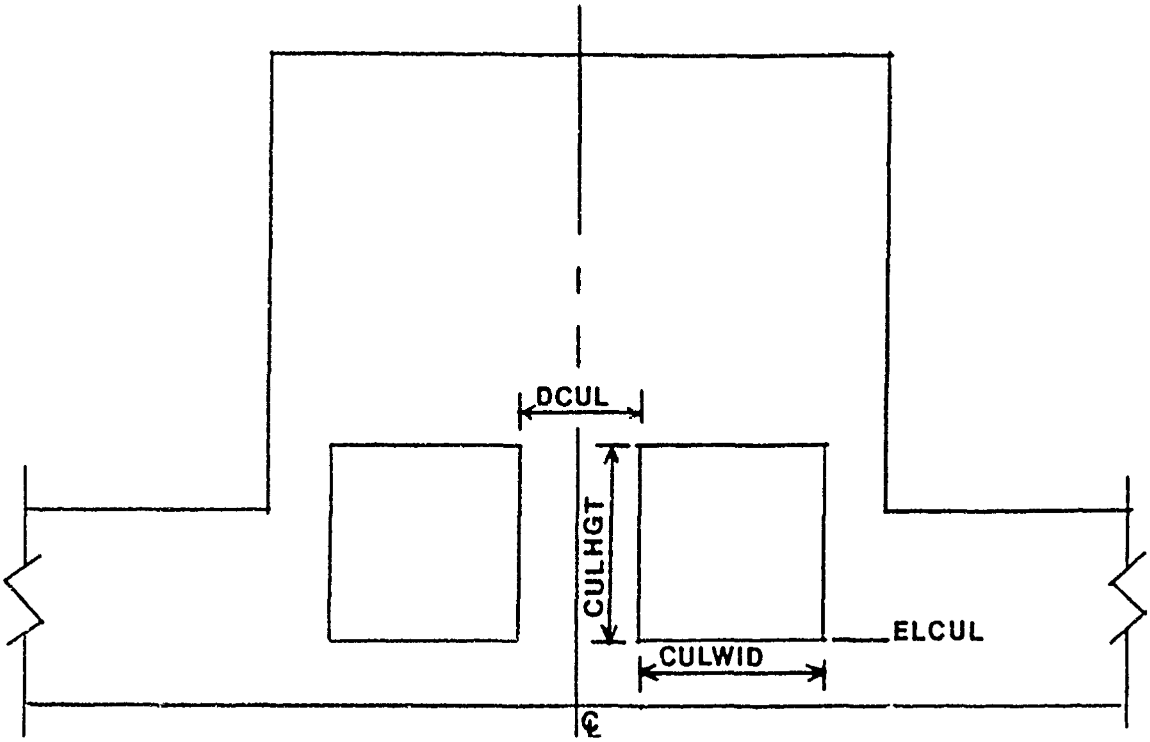
[LN ELTIE(1) HTIE(1) ELTIE(2) HTIE(2) ...

ELTIES(NTIES) HTIE(NTIES)]

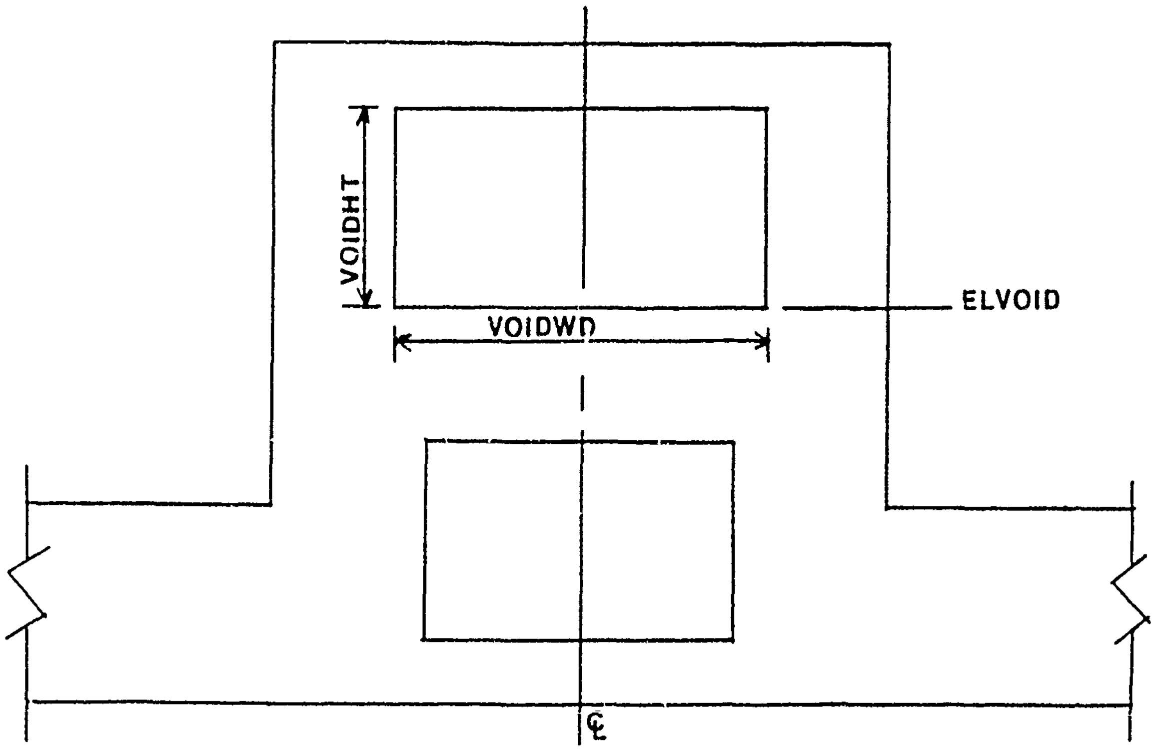
(3) Definitions

'Void Center' = keyword

VOIDWD = width of void opening (FT)



a. Center stem with two culverts



b. Center stem with one culvert and a void

Figure A6. Center stem

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

NTIES = number of horizontal structural members across void opening (0 to 5)

ELTIE(I) = elevation at top of ith tie member (FT)

HTIE(I) = depth of ith tie member (FT)

(4) Discussion

(a) See Figure A5 for notation.

(b) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the center stem and base data.

(c) Void data must satisfy the following:

ELVOID $\geq$ (ELCUL + CULHGT) if culvert present

(ELVOID + VOIDHT) $\leq$ ELCSTM

(d) If (ELVOID + VOIDHT) < ELCSTM, the void is treated as an additional rectangular opening in the stem.

(e) Void ties are intended to provide a means of enforcing interaction between the vertical stem sections on either side of the void opening. The ties are considered to be fictitious concrete (but weightless) members with rectangular cross sections (HTIE X SLICE). They are assumed not to impede free communication of water through the void.

(f) Tie data must commence with the topmost tie and proceed sequentially downward.

(g) Restrictions on tie data are:

ELTIE(1) $\leq$ (ELVOID + VOIDHT)

ELTIE(I) $\leq$ (ELTIE(I - 1) - HTIE(I - 1))

(ELTIE(NTIES) - HTIE(NTIES)) $\geq$ ELVOID

14. BACKFILL

a. Control--Zero (0) or one (1) line. The entire section may be omitted if backfill effects are not to be considered.

(1) Line contents

LN 'BACkfill' ('side') ('type') NUM [SURCH]

(2) Definitions

'BACkfill' = keyword

('side') = 'Rightside', 'Leftside', or 'Both'

('type') = 'Soil' or 'Pressure'

NUM = number (1   5) of horizontal soil layers if 'type' = 'Soil'

= number (2 to 21) of points on input pressure distribution if 'type' = 'Pressure'

[SURCH] = surface surcharge load (PSF), omit if 'type' = 'Pressure'

b. Backfill soil layer data--Omit if 'type' = 'Pressure'; otherwise one line per layer (NUM lines)

(1) Line contents

LN ELLAY GAMSAT GAMMST SCHT SCHB [SCVT SCVB]

(2) Definitions

ELLAY = elevation (FT) at top of layer

GAMSAT = saturated soil unit weight (PCF)

GAMMST = moist soil unit weight (PCF)

SCHT,SCHB = coefficient for horizontal soil pressure at top and bottom of layer, respectively.

[SCVT,SCVB] = coefficient for soil shear stress at top and bottom of layer, respectively. Zero assumed if omitted.

(3) Discussion

(a) See Figure A7 for notation.

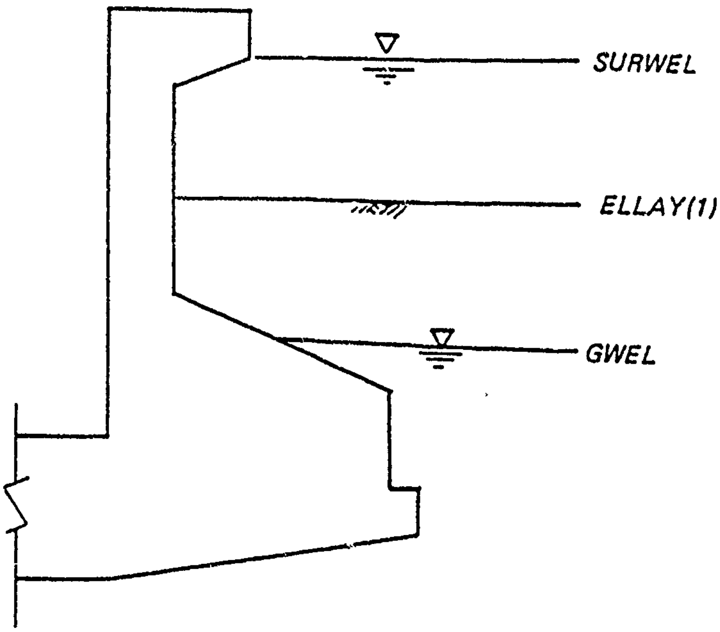


Figure A7. Backfill soil

(b) Soil layer data lines must commence with the topmost layer (layer 1) and proceed sequentially downward. The last layer input is assumed to continue at infinitum downward.

Restrictions:

$ELLAY(1) \leq ELSTEM(1)$

$ELLAY(1) \geq ELBASE(2)$

$ELLAY(I) < ELLAY\ (I - 1)$

(c) Horizontal and shear stress soil coefficients are assumed to vary linearly from top to bottom of the layer. Soil coefficients in the last layer input are assumed to be constant throughout the layer and equal to the values given for the top layer.

(d) If soil lies below ground-water elevation (see section on WATER DATA), effective unit weight is obtained by subtracting the unit weight of water from the saturated soil unit weight. If soil lies above ground-water elevation, the moist unit weight is used.

(e) Horizontal soil pressures and soil shear stresses are obtained at the top and bottom of each layer by multiplying the effective vertical soil pressure by the appropriate soil coefficient of that point. A linear variation of pressure and/or shear stress is assumed from the top to bottom of each layer. If the ground-water elevation occurs within a layer, an additional layer boundary is automatically inserted at that point.

c. Backfill soil pressure distribution--Omit if 'type' = 'Soil'; otherwise one (1) or more lines

(1) Line contents

LN ELPR(1) EVSPR(1) EHSPR(1) ESSPR(1)

[LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]

(2) Definitions

ELPR(I) = elevation (FT) of i^{th} pressure point

EVSPR(I) = effective vertical soil pressure (PSF) at i^{th} pressure point

EHSPR(I) = effective horizontal soil pressure (PSF) at i^{th} pressure point

ESSPR(I) = effective soil shear stress (PSF) at i^{th} pressure point

(3) Discussion

(a) Four values are required at each point on the backfill soil pressure distribution. Data values are provided in groups of four until NUM points are entered. Points must be provided commencing with the topmost point and proceed sequentially downward.

(b) Restrictions:

$ELPR(1) \leq ELSTEM(1)$

ELPR(1) > ELBASE(2)

ELPR(I) < ELPR(I - 1)

EVSPR(I) $\geq$ 0

EHSPR(I) $\geq$ 0

ESSPR(I) $\geq$ 0

d. Discussion of backfill data

(1) If identical backfill conditions exist on both sides of the structure, specify {'side'} = 'Both' and enter data only once. Otherwise, enter data twice: first for 'Rightside' and then for 'Leftside'.

(2) Backfill data are used to determine soil loading on the exterior surface of the outside stem. Effective stresses, vertical, horizontal, and shear, on horizontal and vertical planes of a soil element at the soil structure interface are obtained from soil data or from direct input of soil pressures. A Mohr's circle analysis is used to obtain normal and shear (friction) pressures on the external faces of the outside stem.

(3) Positive effective vertical and horizontal stresses are compression. Positive effective shear stress tends to move the structure downward.

(4) The topmost elevation on the backfill pressure distribution is interpreted as the elevation of the ground surface.

(5) The entire 'BACkfill' data section may be omitted for either or both sides of the structure.

15. BASE REACTION DATA

a. Control--One (1) line

(1) Line contents

LN 'Reaction' {'type'} {'specs'} [{'horizontal option'} {'vertical option'}]

(2) Definitions

'Reaction' = keyword

{'type'} = 'Soil' or 'Pile'

{'specs'} = { 'Uniform'
'Trapezoidal' PCT
'Rectangular' PCT
'Pressure' } , omit if 'type' = 'Pile'

PCT = fraction of uniform base reaction to be applied at centerline (Part IV)

{'horizontal option'} = 'Shear' if unbalanced horizontal loads are to be equilibrated by shear in the base. Omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

= '<u>F</u>riction' if unbalanced horizontal loads are to be equilibrated by friction along structure base; omit if 'type' = '<u>P</u>ile'; omit unless input file contains sequence of problems

('vertical option') = '<u>A</u>djust' if unbalanced vertical loads and moments are to be equilibrated by adjusting base pressure distribution; omit if 'type' = '<u>P</u>ile'; omit unless input file contains sequence of problems

= '<u>S</u>hear' if unbalanced vertical loads and moments are to be equilibrated by shear in the outside stems; omit if 'type' = '<u>P</u>ile'; omit unless 'specs' = '<u>P</u>ressure'; omit unless input file contains sequence of problems

(3) Discussion

(a) Base reaction data must be provided for soil only or pile only. Uplift water forces are entered in the WATER DATA section.

(b) '<u>U</u>niform', '<u>T</u>rapezoidal', and '<u>R</u>ectangular' soil reaction distributions are evaluated automatically to equilibrate all vertical loads and overturning moments.

(c) '<u>P</u>ressure' indicates an input pressure distribution is provided.

(d) '<u>P</u>ile' indicates that pile data are input and no soil reaction is present.

(e) ('horizontal option') and ('vertical option') are to be supplied only if the input file contains a sequence of problems. Otherwise, the user will be requested to enter these options by the program during execution. If these items are omitted for any problem in a sequence or are incorrectly specified, the program will automatically use ('horizontal option') = '<u>F</u>riction' and ('vertical option') = '<u>A</u>djust'

<u>b</u>. Input base-soil pressure distribution--One (1) or more lines. Omit entire section if ('specs') = '<u>P</u>ressure'

(1) Line 1 contents

LN ('side') NPTS DBPR(1) BPR(1) DBPR(2) BPR(2) ...

[LN ... DBPR(NPTS) BPR(NPTS)]

(2) Definitions

('side') = '<u>R</u>ightside', '<u>L</u>eftside', or '<u>B</u>oth'

NPTS = number (2 to 21) of points on input pressure distribution

DBPR(I) = distance (FT) from centerline to the i^{th} pressure point

BPR(I) = base soil pressure (PSF) at i^{th} pressure point

(3) Discussion

(a) The base soil pressure diagram is provided in two parts: one from centerline to extreme rightside of the base and one from centerline to extreme leftside of base. If distribution is symmetric about the centerline, specify {'side'} = 'Both' and enter data only once.

(b) Two values (DBPR and BPR) are required for each point on the distribution. Continue pairs of values on additional lines commencing with a line number, until NPTS pairs have been provided.

(c) Pressure point data must commence with the point nearest centerline and proceed sequentially outward.

Restrictions:

$$DBPR(1) \geq 0$$

$$DBPR(I) > DBPR(I - 1)$$

$$BPR(I) \geq 0$$

(d) If DBPR(I) > 0, base pressure is assumed to be constant at BPR(1) from the centerline to DBPR(1).

(e) Pressure is assumed to be constant at BPR(NPTS) for all points beyond DBPR(NPTS).

(f) CAUTION: An input base pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for adjustments applied to place entire system in equilibrium.

(g) If base pressure distribution are different on each side, enter data for 'Rightside' first and immediately follow with 'Leftside' data.

c. Pile data--Omit entire section if 'type' = 'Soil'

(1) Control--One (1) line

(a) Line contents

LN 'PILe' 'side'

(b) Definitions

'PILe' = keyword

'side' = 'Rightside', 'Leftside', or 'Both'

(2) Pile layout--One (1) to ten (10) lines

(a) Line contents

LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

(b) Definitions

'Layout' = keyword

NSTART = pile number at start of sequence

DSTART - distance from centerline to intersection of pile centerline with base of structure (FT)

[NSTOP] - pile number of last pile in sequence

[NSTEP] - step in pile number

[DSTEP] - distance between [illegible] pile in the sequence (FT)

(c) Discussion

1. Piles on either side of the centerline are designated by an integer number from 1 to 50. A maximum of fifty (50) piles is permitted on each side of the structure. Pile numbers need not be entered in a sequential order. Any pile number in the range 1 to 50 for which layout data are supplied is ignored.

2. Each line of 'Layout' data describes one sequence of piles to be generated.

3. Pile numbers and distances are generated for each sequence as follows:

Pile No.	Distance from Centerline
NSTART	DSTART
NSTART + NSTEP	DSTART + DSTEP
NSTART + (2* NSTEP)	DSTART + (2 * DSTEP)
.	.
.	.
.	.
NSTOP	DSTART + ((NSTOP - NSTEP)/NSTEP) * DSTEP

4. (NSTOP-NSTART)/NSTEP must be an integer.

5. If NSTOP, NSTEP, and DSTEP are all omitted, only one pile is generated.

6. If NSTEP and DSTEP are omitted, NSTEP is assumed to be one and DSTEP is assumed to be zero. This results in piles NSTART, NSTART + 1, NSTART + 2, ..., NSTOP all attached to base of structure at DSTART.

7. If DSTEP is omitted, DSTEP is assumed to be zero. This results in piles NSTART, NSTART + NSTEP, NSTART + (2 * NSTEP), ..., NSTOP all attached to base of structure at DSTART.

8. Any pile generated beyond the extreme edge(s) of the base is ignored.

9. If any pile is referenced more than once, only the data corresponding to the last reference are used.

10. When 'side' = 'Both', DSTART = 0 may result in two (or more) piles being placed at the centerline. See discussion of batter data below.

11. Every pile referenced in the pile "Layout" data must be assigned either pile/soil data or a pile head stiffness matrix as described below.

(3) Pile/soil properties--Zero (0) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'PROperties' NSTART PE PA PI PL PAXCO DF SS1 SS2 [NSTOP [NSTEP]]

(b) Definitions

'PROperties' = keyword

NSTART = pile number at start of sequence

PE = pile modulus of elasticity (PSI)

PA = pile cross-sectional area (IN^2)

PI = pile moment of inertia (IN^4)

PL = pile length (FT)

PAXCO = coefficient for pile axial stiffness

DF = pile head fixity coefficient ($0 \leq DF \leq 1$); 0 = pinned head, 1 = fixed head

SS1 = constant soil stiffness coefficient (LB/IN^2)

SS2 = linear soil stiffness coefficient (LB/IN^3)

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical pile properties, pile head fixity, and soil properties are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2* NSTEP), ..., NSTOP.

3. (NSTOP-NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. If any pile is referenced more than once, only the data for the last reference are used.

7. Soil stiffness is obtained from

$$E_s = SS1 + (SS2 * Y)$$

where E_s is the force per unit length of pile (LB/IN^2) produced by a unit lateral displacement, and Y is the distance below the pile head. Soil stiffness coefficients must include effects of pile width, as well as other factors which may influence the soil stiffness.

8. Pile properties, pile head fixity, and soil properties are used to generate pile head stiffness matrices.

(4) Pile head stiffness matrices--Zero (0) or one (1) to ten (10) entire section may be omitted

(a) Line contents

LN 'STIFfness' NSTART B11 B22 B33 B13 [NSTOP[NSTEP]]

(b) Definitions

'STIFfness' = keyword

NSTART = pile number at start of sequence

B11 = pile lateral stiffness (LB/IN.)

B22 = pile axial stiffness (LB/IN.)

B33 = pile moment stiffness (LB/IN.)

B13 = lateral force-moment coupling stiffness (LB)

[NSTOP] = pile number of the last pile in sequence

[NSTEP] = step in pile number

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical pile head stiffness matrices are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2 * NSTEP, ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. If any pile is referenced more than once, only the data for the last reference are used.

(5) Pile batter data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]

(b) Definitions

'BATter' = keyword

NSTART = pile number of first pile in sequence

BATTER = slope of pile vertical (FT) per foot horizontal. Positive if pile slopes downward away from centerline; negative if pile slopes downward toward centerline

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(c) Discussion.

1. Each line of data describes a sequence of piles to be generated.

2. Identical pile batters are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2 * NSTEP), ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be zero.

6. All piles are assumed to lie in a vertical plane. BATTER describes the slope of the pile within this vertical plane. When BATTER ≥ 100 or BATTER = 0, the pile is assumed to be exactly vertical. Any pile not assigned a batter is assumed to be exactly vertical.

7. When all pile data are symmetric, vertical piles on the structure centerline are not duplicated in mirror image established for the 'Leftside'.

(6) Pile load comparison data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM FPM OSFC OSFT [NSTOP [NSTEP]]

(b) Definitions

'ALLOWables' = keyword

NSTART = pile number at start of sequence

AC = allowable pile axial compression force (KIPS)

AT = allowable pile axial tension force (KIPS)

ACC = allowable pile axial compression force for combined axial compression and bending (KIPS)

ATT = allowable pile axial tension force for combined axial tension and bending (KIPS)

AM = allowable bending moment (KIP-FT)

FMM = moment magnification factor for amplification effect of axial compression on bending moment

FPM = factor (IN.) for evaluating maximum bending moment in pinned head pile (i.e., DF = 0 or B13 and B33 both equal zero); input value is ignored for piles that transfer moment at pile head

OSFC = load case factor for pile in compression

OSFT = load case factor for pile in tension

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical "allowable" data values are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2 * NSTEP), ..., NSTOP.

3. (NSTOP-NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. If any pile is referenced more than once, only the data for the last reference are used.

7. The following ratios are evaluated and reported:

$\lvert FA/OSFC \rvert /AC$	for axial compression
$\lvert FA/OSFT \rvert /AT$	for axial tension
$(\lvert FA/ACC \rvert + FMM \lvert BM/AM \rvert)/OSFC$	for axial compression
$(\lvert FA/ATT \rvert + \lvert BM/AM \rvert)/OSFT$	for axial tension

where: FA = calculated pile axial head force

BM = bending moment at pile head for nonpinned head piles

BM = (FPM * FV), where FV = pile head shear for pinned head piles

8. "ALLOWable" data need to be entered only for piles for which comparison are desired. No comparisons are performed for any pile not assigned "ALLOWable" data.

9. Comparison are made for information purposes only. No action is taken by the program based on the values of the ratios.

10. Values for the load case factors OSFC and OSFT should be selected based on severity and duration expected for the particular loading condiion. It may be necessary to alter OSFC and OSFT for each loading condition to obtain valid comparisons for the loads.

(7) General discussion of pile data

(a) Pile layout data are used to determine the number of piles present and their identification. Every pile defined by the layout data must be assigned pile/soil data or pile head stiffness matrix; otherwise execution will terminate.

(b) Any pile number assigned pile/soil data or pile head stiffness matrix but not defined by layout data is ignored.

(c) If different pile conditions exist on each side, enter the entire description for 'Rightside' piles ('Layout', 'PROperties', 'STIFFnesses', 'BATter', and 'ALLOWables') first and immediately follow with 'Leftside' data.

16. WATER DATA

a. Control--Zero (0) or one (1) line. Omit entire section if water effects are not to be considered.

(1) Line contents

LN 'Water' [GAMWAT]

(2) Definitions

'Water' = keyword

[GAMWAT] = unit weight of water (PCF). Assumed to be 62.4 PCF if omitted

b. External water--Zero (0), one (1), or two (2) or more lines. Entire section may be omitted.

(1) Control--One (1) line

(a) Line contents

LN 'External' {'side'} {'type'} [ELGW [ELSURW]]

(b) Definitions

'External' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'type'} = 'Elevation' if external water effects are to be calculated from input water elevations

= 'Pressure' if water pressure distribution provided

[ELGW] = elevation (FT) of ground-water surface; omit if {'type'} = 'Pressure'

[ELSURW] = elevation (FT) of surcharge water surface; omit if surcharge water is not to be considered; omit if {'type'} = 'Pressure'

(c) Discussion for {'type'} = 'Elevation'

1. Ground water affects backfill soil loads by altering effective soil unit weight as well as producing horizontal hydrostatic pressures on the lateral surface of the structure.

2. Surcharge water is assumed to lie above the ground surface and to be isolated from ground water. Surcharge water produces hydrostatic pressures on the lateral surface of the structure. Vertical pressure of surcharge water on the ground surface is added to effective vertical soil pressures when soil layer data are provided in the backfill description.

Restrictions:

ELSURW $\leq$ ELSTEM(1)

ELSURW > ELLAY(1) if backfill soil data provided

ELSURW > ELPR(1) if backfill pressure distribution provided

(2) Data lines if {'type'} = 'Pressure'

(a) Line contents

LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2) ...

[LN ... ELWPRE(NPTS) WPRE(NPTS)]

(b) Definitions

NPTS = number (2 to 21) of points on pressure distribution provided

ELWPRE(I) = elevation (FT) at i^{th} pressure point

WPRE(I) = pressure (PSF) at i^{th} pressure point

(c) Discussion

1. Elevation and pressure data are provided in pairs. Data pairs may be continued on additional lines following a line number until NPTS pairs have been provided.

2. Input water pressures act normal to the exterior surfaces of the structure between ELWPRE(1) and ELBASE(2). No other water effect is implied or used.

Restrictions:

ELWPRE(1) ≤ ELSTEM(1)

ELWPRE(I) < ELWPRE(I - 1)

ELWPRE(I) ≥ ELBASE(2)

3. Input water pressure distribution produces only loads normal to the lateral surfaces of the structure. No other effect is implied or used.

(3) Discussion of external water data

(a) See Figure A8 for notation.

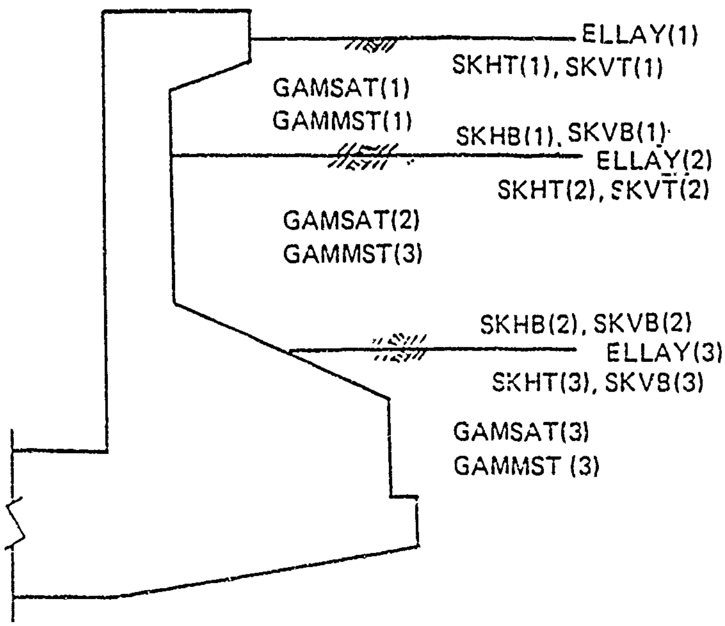


Figure A8. External water

(b) If identical external water effects exist on both sides of the structure, enter ('side') = 'Both' and enter data only once. If different effects exist on the two sides, enter data twice: first for 'Rightside' and then 'Leftside'.

c. Uplift water effects on base--Zero (0) or one (1) or more lines. Entire section may be omitted

(1) Control--One (1) line

(a) Line contents

LN 'Uplift' ('type') [UPRITE [UPLEFT]]

(b) Definitions

'Uplift' = keyword

('type') = 'Elevation' if uplift pressures are to be calculated from input elevations

= 'Pressure' if uplift pressure distribution is provided

[UPRITE] = effective uplift water elevation at extreme rightside of base (FT); omit if ('type') = 'Pressure'

[UPLEFT] = effective uplift water elevation at extreme leftside of base (FT); assumed to be equal to UPRITE if omitted; omit if ('type') = 'Pressure'

(c) Discussion for ('type') = 'Elevation'

1. Uplift pressures on the base are obtained by multiplying the weight of water by the input heads at the extremes of the base.

2. Uplift pressure is assumed to vary linearly between the extremes.

Restrictions:

UPRITE $\geq$ ELBASE(2) on rightside

UPLEFT $\geq$ ELBASE(2) on leftside

3. A straight line between UPRITE and UPLEFT must not intersect the base of the structure at any point.

(2) Input base uplift pressure distribution--One (1) or more lines. Omit entire section if ('type') = 'Elevation'

(a) Line contents.

LN ('side') NPTS DUPR(1) UPR(1) DUPR(2) UPR(2) ...

[LN ... DUPR(NPTS) UPR(NPTS)]

(b) Definitions.

('side') = 'Rightside', 'Leftside', or 'Both'

NPTS = number (1 to 21) of points on the input pressure distribution

DUPR(I) = distance (FT) from centerline to i^{th} pressure point

UPR(I) = uplift pressure (PSF) at i^{th} pressure point

(c) Discussion.

1. The base uplift pressure diagram is provided in two parts: first from centerline to extreme rightside of base; then from centerline to extreme leftside of base. If the distribution is symmetric about the centerline, specify ('side') = 'Both' and enter data only once.

2. Two values (DUPR and UPR) are required for each point on the distribution. Continue pairs of values on additional lines, commencing with a line number, until NPTS pairs have been provided.

3. Pressure point data must begin with the point nearest the centerline and proceed sequentially outward.

Restrictions:

$\text{DUPR}(1) \geq 0$

$\text{DUPR}(I) > \text{DUPR}(I - 1)$

$\text{UPR}(I) \geq 0$

4. If DUPR(I) > 0, uplift pressure is assumed to be constant at UPR(1) from the centerline to DUPR(1).

5. Uplift pressure is assumed to be constant at UPR(NPTS) for all points beyond DUPR(NPTS).

6. CAUTION: An input uplift pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for reaction adjustments applied to place the entire system in equilibrium.

d. Internal water (U-FRAME structure)--Zero (0) or one (1) line. Entire section may be omitted.

(1) Line contents

LN 'Internal' ELCHMW [[ELCWR] [ELCWL]]

(2) Definitions

'Internal' = keyword

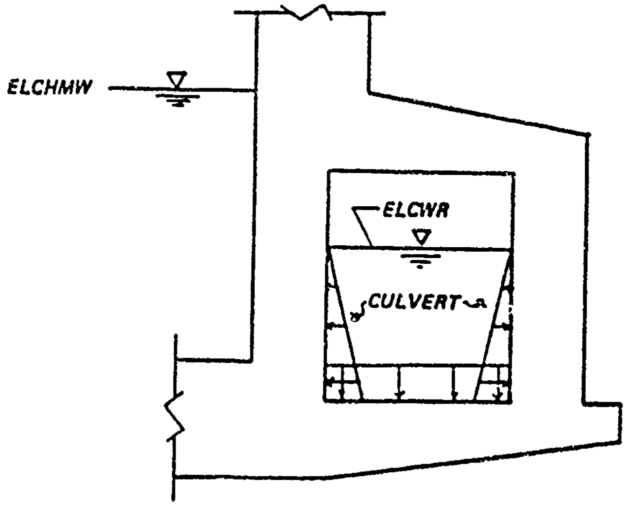
ELCHMW = water elevation in chamber (FT)

[ELCWR] = effective water elevation in rightside culvert (and stem void) (FT); omit if culvert is not present

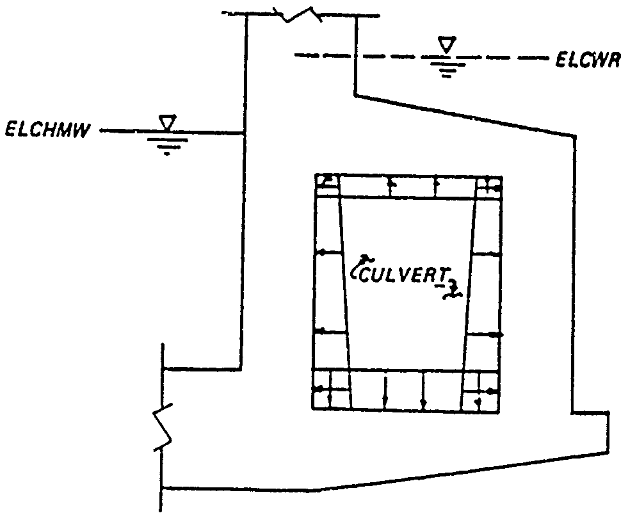
[ELCWL] = effective water elevation in leftside culvert (and stem void) (FT); omit if culvert is not present

(3) Discussion

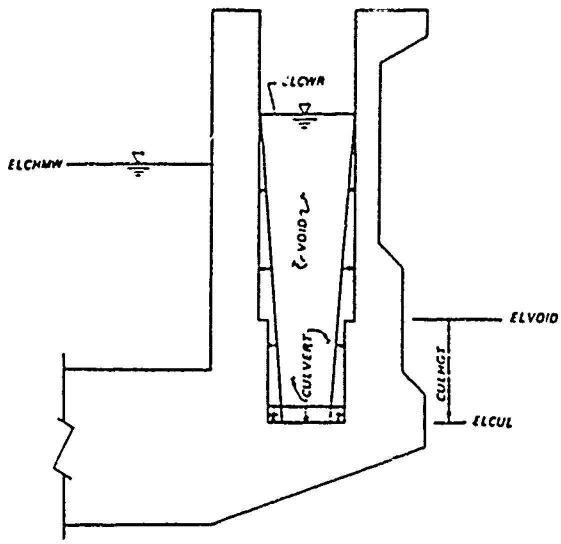
(a) See Figure A9 for notation



a. Culvert partially filled



b. Culvert fully pressurized



c. Void and culvert connected

Figure A9. Internal water (U-FRAME structure)

(b) If ELCHMW is less than ELFLOR, the chamber is assumed to be dry. ELCHMW must be less than or equal to ELSTEM(1).

(c) If effective water elevation in the culvert(s) is less than ELCUL (rightside or leftside), the culvert is assumed to be dry.

(d) If the culvert top is closed, i.e., ELVOID $\geq$ (ELCUL + CULHGT), and the effective water elevation in the culvert is above the top of the culvert, the culvert is assumed to be pressurized. In this case the stem void (if present) is assumed to be dry.

(e) If the culvert is open to the stem void, i.e., ELVOID = (ELCUL + CULHGT), then the interior walls of the culvert (and void) are subjected only to triangular hydrostatic pressures.

(f) Culvert water elevation may result in hydrostatic pressures on all interior surfaces of a closed culvert. If the culvert is open to the stem void and stem void is closed at the top, i.e., (ELVOID + VOIDHT) < ELSTEM(1), culvert water elevation may result in hydrostatic pressures on all interior surfaces of the culvert and void.

e. Internal water (W-FRAME structure)--Zero (0) or one (1) or two (2) lines. Entire section may be omitted.

(1) Line(s) contents

LN 'Internal' {'side'} ELCHMW [ELCLWS [ELCLWC]]

(2) Definitions

'Internal' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

ELCHMW = water elevation in chamber (FT)

ELCLWS = effective water elevation in outside stem culvert (and outside stem void) (FT)

ELCLWC = effective water elevation in center stem culvert (FT)

(3) Discussion

(a) See Figure A10 for notation

(b) If ELCHMW is less than ELFLOR, the associated chamber is assumed to be dry. ELCHMW must be less than or equal to ELCSTM and the appropriate ELSTEM(1).

(c) If effective water elevation in any culvert is less than ELCUL for that culvert, the culvert is assumed to be dry.

(d) If an outside stem culvert has a closed top, i.e., ELVOID > (ELCUL + CULHGT), and the effective water elevation in the culvert is above the top of the culvert, the culvert is assumed to be pressurized. In

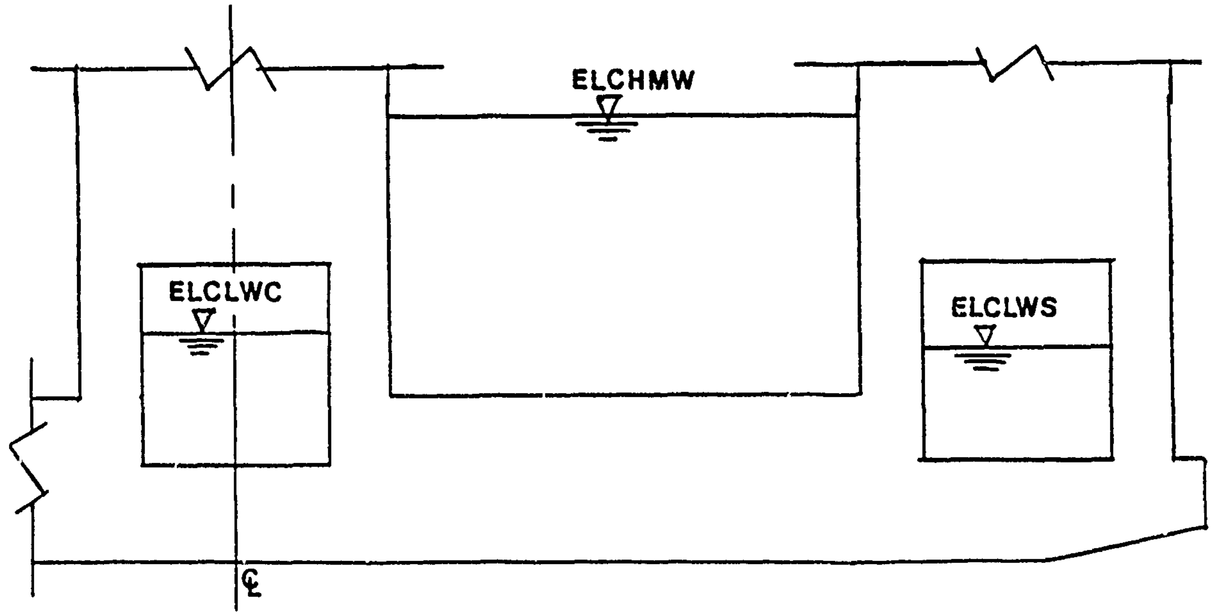


Figure A10. Internal water (W-FRAME structure)

this case the stem void (if present) is assumed to be dry.

(e) If the effective water elevation in a center culvert is above the top of the culvert, the culvert is assumed to be pressurized.

(f) If an outside stem culvert is open to the stem void, i.e., ELVOID = (ELCUL + CULHGT), then the interior walls of the culvert (and void) are subjected only to triangular hydrostatic pressures.

(g) Culvert water elevation may result in hydrostatic pressures on all interior surfaces of a closed culvert. If an outside stem culvert is open to the stem void and the stem void is closed at the top, i.e., (ELVOID + VOIDHT) < ELSTEM(1), culvert water elevation may result in hydrostatic pressures on all interior surfaces of the culvert and void.

17. ADDITIONAL LOAD DATA--Zero (0), one (1), or two (2) or more lines. Entire section may be omitted or line sequences may be repeated as necessary.

a. Control--One (1) line

(1) Outside Stem

(a) Line contents

LN 'Loads' {'side'} {'location'}

(b) Definitions

'Loads' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both' ('location') = 'Stem Exterior' if loads act on exterior face of stem

= 'Stem Interior' if loads act on interior face of stem

= 'Stem Top' if loads act on top horizontal surface of stem

(2) Floor and Base

(a) Line contents

LN 'Loads' ('side') ('location')

(b) Definitions

'Loads' = keyword

('side') = 'Rightside', 'Leftside', or 'Both'

('location') = 'Floor' if loads act on chamber floor
= 'Base' if loads act on base of structure

(3) Center Stem

(a) Line contents

LN 'Loads' 'Center' ('location') ('side')

(b) Definitions

'Loads' 'Center' = keywords

('location') = 'Face' if loads act on face of stem

= 'Top' if loads act on top horizontal surface of stem

('side') = 'Rightside', 'Leftside', or 'Both'

(4) Earthquake acceleration

(a) Line contents

LN 'Loads' 'Earthquake' HACC VACC

(b) Definitions

'Loads' 'Earthquake' = keywords

HACC = horizontal acceleration (G's)

VACC = vertical acceleration (G's)

(c) Discussion

1. Control and data are given on one line.

2. Absolute value of acceleration must be equal to or less than one (1).

3. Horizontal acceleration is positive if it acts toward the right.

4. Vertical acceleration is positive if it acts upward.

5. Earthquake accelerations are applied to the concrete only.

b. Data lines for loads acting on stem faces

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1) ...

[LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated loads

ELCSLD = elevation at which load acts (FT)

HCSLD = magnitude of horizontal load component (PLF)

VCSID = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1) ...

[LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

ELDSLD(I) = elevation at i^{th} load point (FT)

HDSLD(I) = magnitude of horizontal load at i^{th} load point (PSF)

VDSLD(I) = magnitude of vertical load at i^{th} load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward the centerline.

(b) All vertical loads are positive if they act downward.

(c) For concentrated loads on exterior face of outside stem:

$$ELBASE(2) \leq ELCSLD \leq ELSTEM(1)$$

(d) For concentrated loads on interior face of outside stem:

$$ELFLOR \leq ELCSLD \leq ELSTEM(1)$$

(e) For concentrated loads on face of center stem:

ELFLOR ≤ ELCSLD ≤ ELCSTM

(f) Concentrated loads are interpreted as line loads acting on the slice.

(g) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) Distributed loads on the exterior face of outside stem must begin at or below the top of the stem and terminate at or above the juncture of the base and stem, i.e.,

ELDSLD(1) ≤ ELSTEM(1)

ELDSLD(I) ≤ ELDSLD(I - 1)

ELDSLD(NPTS) ≥ ELBASE(2)

(i) Distributed loads on the interior face of outside stem must begin at or below the top of the stem and terminate at or above the chamber floor, i.e.,

ELDSLD(1) ≤ ELSTEM(1)

ELDSLD(I) ≤ ELDSLD(I - 1)

ELDSLD(NPTS) ≥ ELFLOR

(j) Distributed loads on the face of center stem must begin at or below the top of the stem and terminate at or below the chamber floor, i.e.,

ELDSLD(1) ≤ ELCSTM

ELDSLD(I) ≤ ELDSLD(I - 1)

ELDSLD(NPTS) ≥ ELFLOR

(k) Distributed loads are assumed to vary linearly between input points.

(l) If two load points are specified at the same elevation, the first is assumed to exist immediately above the elevation and the second immediately below the elevation.

(m) Distributed loads are interpreted as force per foot of slice per foot of vertical projection of the stem surface.

c. Data lines for loads acting on top horizontal surface of stem

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS DCSTLD(1) HCSTLD(1) VCSTLD(1) ...

[LN ... DCSTLD(NLDS) HCSTLD(NLDS) VCSTLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated loads

DCSTLD = distance from inside stem face at which load acts (FT)

HCSTLD = magnitude of horizontal load component PLF)

VCSTLD = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1) ...

[LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

DDSTLD(I) = distance from inside stem face to i^{th} load point (FT)

HDSTLD(I) = magnitude of the horizontal load at i^{th} load point (PSF)

VDSTLD(I) = magnitude of the vertical load at i^{th} load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward the centerline.

(b) All vertical loads are positive if they act downward.

(c) If the top of a stem void is open at the top of the stem, loads may not be applied inside of the void opening.

(d) For concentrated loads on top of outside stem:

$$0.0 \leq \text{DCSTLD(I)} \leq \text{DSTEM(1)}$$

(e) For concentrated loads on top of center stem:

$$0.0 \leq \text{DCSTLD(I)} \leq \text{CSTMWD/2}$$

(f) Concentrated loads are interpreted as line loads acting on the slice.

(g) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) For distributed loads on top of outside stem:

$0.0 \leq DDSTLD(I) \leq DSTEM(1)$

$DDSTLD(I) \geq DDSTLD(I - 1)$

(i) For distributed loads on top of center stem:

$0.0 \leq DDSTLD(I) \leq CSTMWD/2$

$DDSTLD(I) \geq DDSTLD(I - 1)$

(j) Distributed loads are assumed to vary linearly between input points.

(k) If two points are input at the same distance from the stem face, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

(l) Distributed loads are interpreted as force per foot of slice per foot of horizontal stem top surface.

d. Data lines for loads acting on chamber floor and structure base

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...

[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated loads

DCFBLD = distance from centerline at which load acts

HCFBLD = magnitude of horizontal load component (PLF)

VCFBLD = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1) ...

[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

DDFBLD(I) = distance from centerline to i^{th} load point (FT)

HDFBLD(I) = magnitude of horizontal load at i^{th} load point (PSF)

VDFBLD(I) = magnitude of vertical load at i^{th} load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward centerline

(b) All vertical loads are positive if they act downward

(c) For concentrated loads on the chamber floor of a U-FRAME structure:

$$0.0 \leq \text{DCFBLD(I)} \leq \text{FLRWID}$$

(d) For concentrated loads on a chamber floor of a W-FRAME structure:

$$\text{CSTMWD/2} \leq \text{DCFBLD(I)} \leq \text{FLRWID}$$

(e) For concentrated loads on the structure base

$$0.0 \leq \text{DCFBLD(I)} \leq \text{DBASE(2)}$$

(f) Concentrated loads are interpreted as line loads acting on the slice.

(g) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) For distributed loads on the chamber floor of a U-FRAME structure:

$$0.0 \leq \text{DDFBLD(1)}$$

$$\text{DDFBLD(I)} \geq \text{DDFBLD(I - 1)}$$

$$\text{DDFBLD(NPTS)} \leq \text{FLRWID}$$

(i) For distributed loads on a chamber floor of a W-FRAME structure:

$$\text{CSTMWD/2} \leq \text{DDFBLD(1)}$$

$$\text{DDFBLD(I)} \geq \text{DDFBLD(I - 1)}$$

$$\text{DDFBLD(NPTS)} \leq \text{FLRWID}$$

(j) For distributed loads on structure base

$$0.0 \leq \text{DDFBLD(1)}$$

$$\text{DDFBLD(I)} \geq \text{DDFBLD(I - 1)}$$

$$\text{DDFBLD(NPTS)} \leq \text{DBASE(2)}$$

(k) If two points are input at the same distance from the stem face, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

(1) Distributed loads are interpreted as force per foot of slice per foot of horizontal projection of the base.

18. LIST OF MEMBERS FOR DETAILED MEMBER FORCE OUTPUT--Zero (0), one (1), or two (2) lines. Omit unless input file contains sequence of problems; omit if 'mode' = 'Equilibrium'.

a. Line contents

[LN 'Output Members' ('side') (list)]

b. Definitions

'Output Members' = keywords

('side') = 'Rightside', 'Leftside', or 'Both'

(list] = list of members for which detailed are member forces are desired

= 'All' if detailed for all members are desired

= list of individual member numbers of the form N1 N2 ... N6 N7 ...

c. Discussion

(1) When data are entered from the terminal or from a file containing only one problem, the user is requested to provide this information during program execution.

(2) If this section is omitted, no detailed member forces are output during a sequence of solutions.

(3) For symmetric systems, enter data for 'Rightside' only.

(4) For unsymmetric systems, if different lists of member numbers are desired for the two sides, enter data for 'Rightside' first and immediately follow with data for 'Leftside'.

(5) For W-FRAME structures, if this section is entered, all member forces for the center stem will be output.

19. TERMINATION--One (1) line

a. Line contents

LN 'Finish' ['Rerun']

b. Definitions

'Finish' = keyword to indicate end of problem data set

['Rerun'] = keyword to indicate additional problem data set follows for sequence of problems. Omit unless input file contains a sequence of problems. Omit on last line of sequence.

Abbreviated Input Guide

20. CONTROL

    a. Heading--One (1) to four (4) lines

       LN 'heading'

       [LN 'heading']

       [LN 'heading']

       [LN 'heading']

    b. Method--One (1) line

       LN 'Method' ('Equilibrium')

       ('Frame' RLF)

21. STRUCTURE

    a. Control--One (1) line

       LN 'Structure' EC PR WTCONC [SLICE]

    b. Floor--One (1) line

       LN 'Floor' FLRWID ELFLOR [FLRFIL]

    c. Base--One (1) or two (2) lines

       LN 'Base' ('side') DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]

    d. Stem--One (1) to four (4) lines

       LN 'Stem' ('side') NPTS DSTEM(1) ELSTEM(1) ...

       [LN ... DSTEM(NPTS) ELSTEM(NPTS)

    e. Culvert--Zero (0) to two (2) lines

       [LN 'Culvert' ('side') DCUL CULWID ELCUL CULHGT [CULFIL]]

    f. Void--Zero (0) to four (4) lines

       [LN 'Void' ('side') DVOID VOIDWD ELVOID VOIDHT [NTIES]]

       [LN ELTIE(1) HTIE(1) ... ELTIE(NTIES) HTIE(NTIES)]

    g. Center Stem--Zero (0) or one (1) line

       [LN 'Stem Center' CSTMWD ELCSTM]

    h. Center Culvert--Zero (0) or one (1) line

       [LN 'Culvert Center' NCUL CULWID ELCUL CULHGT [DCUL]]

    i. Center Void--Zero (0) or one (1) to four (4) lines

       [LN 'Void Center' VOIDWD ELVOID VOIDHT [NTIES]]

       [LN ELTIE(1) HTIE(1) ... ELTIE(NTIES) HTIE(NTIES)]

22. BACKFILL

    a. Soil data--Omit if pressure distribution input

(1) Control--One (1) line

LN 'BACkfill' ('side') 'Soil' NUM [SURCH]

(2) Layer data--One (1) to five (5) lines

LN ELLAY GAMSAT GAMMST SCHB SCHB [SCVT SCVB]

b. Pressure data--Omit if soil data input

(1) Control--One (1) line

LN 'BACkfill' ('side') 'Pressure' NUM

(2) Data lines

LN ELPR(1) EVSPR(1) EHSPR(1) ESSPR(1) ...

[LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]

23. BASE REACTION

a. Soil reaction--One (1) to three (3) lines

```
LN 'Reaction' 'Soil' { 'Uniform'            }
                     { 'Trapezoidal' PCT    } [ { 'Shear'    } { 'Adjust' } ]
                     { 'Rectangular' PCT    } [ { 'Friction' } { 'Shear'  } ]
                     { 'Pressure'           }
```

Additional lines for 'Pressure'

LN ('side') NPTS DBPR(1) BPR(1) DBPR(2) BPR(2) ...

[LN ... DBPR(NPTS) BPR(NPTS)]

b. Pile reaction

(1) Control--Two (2) lines

LN 'Reaction' 'Pile'

LN 'Pile' ('side')

(2) Pile layout--One or more lines

LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

(3) Pile properties--Zero (0) or one (1) to ten (10) lines; required if pile head stiffness matrices are calculated by program

LN 'PROperties' NSTART PE PD PA PI PL PAXCO DE SS1 SS2 [NSTOP [NSTEP]]

(4) Pile stiffness matrices--Zero (0) to ten (10) lines

LN 'STIFfness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]

(5) Pile batter--Zero (0) to ten (10) lines

LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]

(6) Pile load comparison--Zero (0) to ten (10) lines

LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM FPM OSFC

OSFT [NSTOP [NSTEP]]

24. WATER

a. Control--Zero (0) or one (1) line

LN 'Water' [GAMWAT]

b. External water--Zero (0) or one (1) or more lines

(1) Water elevations input--One (1) line

LN 'External' {'side'} 'Elevation' ELGW [ELSURW]

(2) Water pressure distribution input--Two (2) or more lines

(a) Control--One (1) line

LN 'External' {'side'} 'Pressure'

(b) Data lines--One (1) or more lines

LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2)

[LN ... ELWPRE(NPTS) WPRE(NPTS)]

c. Uplift water--Zero (0) or one (1) or more lines

(1) Uplift water elevations input--One (1) line

LN 'Uplift' 'Elevation' UPRITE [UPLEFT]

(2) Uplift pressure distribution input--Two (2) or more lines

(a) Control--One (1) line

LN 'Uplift' 'Pressure'

(b) Data lines--One (1) or more lines

LN {'side'} NPTS DUPR(1) UPR(1) DUPR(2) UPR(2) ...

[LN ... DUPR(NPTS) UPR(NPTS)]

d. Internal water--Zero (0) or one (1) or two (2) lines

(1) U-FRAME structure--One (1) line

LN 'Internal' ELCHMW [ELCWR [ELCWL]]

OR

(2) W-FRAME structure--One (1) or two (2) lines

LN 'Internal' {'side'} ELCHMW [ELCLWS [ELCLWC]]

25. ADDITIONAL LOADS

a. Loads on stem faces--Zero (0) or two (2) or more lines

(1) Control--One (1) line

(a) Outside Stem--One (1) line

LN 'Loads' ('side') ('Stem Exterior') ('Stem Internal')

OR

(b) Center Stem--One (1) line

LN 'Loads' 'Center' 'Face' ('side')

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1) ...

[LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1) ...

[LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

b. Loads on stem top--Zero (0) or two (2) or more lines

(1) Control--One (1) line

(a) Outside Stem--One (1) line

LN 'Loads' ('side') ('Stem Top')

OR

(b) Center Stem--One (1) line

LN 'Loads' 'Center' 'Top' ('side')

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCSTLD(1) HCSTLD(1) VCSTLD(1) ...

[LN ... DCSTLD(NLDS) HCSTLD(NLDS) VCSTLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1) ...

[LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

c. Loads on chamber floor or structure base--Zero (0) or two (2) or more lines

(1) Control--One (1) line

LN 'Loads' ('side') ('Floor') ('Base')

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...

[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1)

[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

d. Earthquake acceleration--Zero (0) or one (1) line

LN 'Loads' 'Earthquake' HACC VACC

26. DETAILED MEMBER FORCE LIST--Zero (0) or one (1) or two (2) lines

LN 'Output Members' {'side'} {'All'} {list }

27. TERMINATION--One (1) line

LN 'Finish' ['Rerun']

APPENDIX B: GTSTRUDL SOLUTIONS

STRUDL Model

1. Joints in the STRUDL model were assigned at the locations of the j‹ ıts in the CUFRAM model. Additional STRUDL joints were located at the ends of the flexible lengths of the CUFRAM members at the intersection of any piles with the structure base and at the base of STRUDL members simulating the piles.

2. STRUDL members corresponding to prismatic flexible CUFRAM members were assigned cross-sectional areas and moments of inertia calculated from the dimensions of the structure. Because STRUDL does not have the direct capability of evaluating the stiffness matrix for a tapered member, the stiffness matrices for tapered members wer‘ obtained by the process used in CUFRAM and provided to STRUDL. All STRUDL members representing rigid links in the CUFRAM model were assigned area and inertia properties several times larger than those of the largest prismatic member. Pile head stiffnesses were evaluated separately and supplied to STRUDL as member stiffness matrices.

3. Loads were applied to the STRUDL model as follows. Uniform loads on prismatic members were applied as member loads. Nonuniform loads on prismatic members and loads acting on tapered members were converted by the processes employed in CUFRAM to fixed end forces which were applied to the STRUDL model as equivalent joint loads.

Interpretation of Results

4. With due regard to the sign conventions employed by the two programs, joint displacements, pile head forces, and member end forces for prismatic members with uniform loads may be compared directly. For members with nonuniform loads and for tapered members, fixed end forces must be added to the member end forces reported by STRUDL for comparison with CUFRAM results. Figures B1, B2, and B3 show the GTSTRUDL solutions for CUFRAM Examples 1, 2B, and 3.

```
STRUDL 'CUEX1' 'GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$ CUFRAM MODEL JOINTS
1 0        38       S
2 46.85482 38.46681
3 68       40.5
4 44.5     85
5 45.89617 99.30601
$ JOINTS AT ENDS OF FLEXIBLE LENGTHS
21 43.21371 38
23 50.71371 38.83786
24 47.08435 42.61670
54 44.5     96.07650
MEMBER INCIDENCES
$ CUFRAM MODEL MEMBERS
1 1  21
2 23 3
3 24 4
4 4  54
$ RIGID LINKS
12 21 2
23 2  23
24 2  24
45 54 5
MEMBER PROPERTIES
1 PRISMATIC AX 12 AY 10       IZ 144
4 PRISMATIC AX 5  AY  4.16667 IZ 10.41667
2 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 2.99107E8  0          0
ROW 2 0          2.97866E7 -2.12036E8
ROW 6 0         -2.12036E8  2.71740E9
3 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.41039E8  0          0
ROW 2 0          2.04180E6 -2.88996E7
ROW 6 0         -2.88996E7  6.91650E8
$ RIGID LINKS
12 23 24 45 PRISMATIC AX 5000 IZ 7.0E4
CONSTANTS E 4.32E8
CONSTANTS G 1.80E8
LOADING 1
$ MEMBER UNIFORM LOADS
MEMBER 1 LOADS FORCE Y UNIFORM W 718.96431 LA 0 LB 42
JOINT LOADS
$ FORCES ON RIGID BLOCKS
2 FORCE X -7.24510E3 Y  3.99060E4 MOMENT Z -3.27413E4
5 FORCE              Y -9.15000E3
$ EQUIVALENT JOINT LOADS FOR NONUNIFORM MEMBER LOADS AND HEEL END
23 FORCE X -5.36059E3 Y  2.82199E3 MOMENT Z  3.84311E3
 3 FORCE X -2.67843E4 Y -2.03241E3 MOMENT Z -4.38534E3
24 FORCE X  1.60821E4 Y -3.06778E4 MOMENT Z -1.36362E5
 4 FORCE X  2.48555E4 Y -2.76787E4 MOMENT Z  1.53179E5
54 FORCE X  8.13637E2 Y -3.38555E3 MOMENT Z  2.15505E3
```

Figure B1. GTSTRUDL solution for CUFRAM Example 1--type 1 monolith (Continued)

```
LOADING LIST ALL
STIFFNESS ANALYSIS
$ CUFRAM MODEL JOINTS
LIST DISPLACEMENTS JOINTS 2 3 4 5

  ****************************
  *RESULTS OF LATEST ANALYSES*
  ****************************

   PROBLEM - CUEX1     TITLE - GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH
   ACTIVE UNITS  FEET LB   RAD  DEGF SEC

JOINT                X DISP.          Y DISP.          Z ROT.

2                    .0005850         -.0326286        -.0012112
3                    .0029568         -.0582332        -.0012116
4                    .0780203         -.0287878        -.0018994
5                    .1055526         -.0315560        -.0019367

$ CUFRAM MODEL MEMBERS
 LIST FORCES MEMBERS 1 2 3 4

MEMBER   JOINT            AXIAL            SHEAR Y            BENDING Z

1        1           -2361.2525702        -.0215749     1967114.6154055
1        21           2361.2525702   -30196.4794451    -1296339.2310624
2        23          26855.8610118     -540.5055160       -5001.0877435
2        3          -26855.8610118      540.5055160       -4385.3400002
3        24          41701.9931512   -23174.0112030     -850468.5272026
3        4          -41701.9931512    23174.0112030     -133546.7566838
4        4           12535.5527747      813.6429889       19632.2433158
4        54         -12535.5527747     -813.6429889      -10619.9267494
 FINISH
```

Figure B1. (Concluded)

```
STRUDL 'EX2B' 'GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH'

TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$
$  RIGHTSIDE CUFRAM MODEL JOINTS
$
 1     0          19
'R2'  10          19
'R3'  20          19
'R4'  30          19
'R5'  40          19
'R6'  46          19                    $ RIGID BLOCK 2
'R7'  55          18
'R8'  60          18
'R9'  64          18                    $ RIGID BLOCK 1
'R10' 63.94286 35.19286                 $ RIGID BLOCK 4
'R11' 46          36.5                  $ RIGID BLOCK 3
'R12' 44          55.5
'R13' 46.29543 70.55508                 $ RIGID BLOCK 6
$
$ RIGHTSIDE JOINTS AT ENDS OF FLEXIBLE LENGTHS
$
'R65'    42 19
'R67'    50 18
'R98'    62 18
'R910'   64 21
'R109'   64 33
'R1011'  62 35.375
'R611'   46 23
'R116'   46 33
'R1110'  50 36.5
'R1112'  46 40
'R1312'  44 65.5
$
$ RIGHTSIDE JOINTS ON BASE AT PILE HEADS
$
'BP19'    0  15
'RBP2'    10 15
'RBP310'  20 15
'RBP4'    30 15
'RBP511'  40 15
'RBP12'   45 15
'RBP613'  50 15
'RBP714'  55 15
'RBP8'    60 15
$
$ RIGHTSIDE JOINTS AT BOTTOM OF PILES (FICTITIOUS)
$
$ VERTICAL PILES
'PB19'    0  10 S
'RPB2'    10 10 S
'RPB310'  20 10 S
'RPB4'    30 10 S
```

Figure B2. GTSTRUDL solution for CUFRAM Example 2B--type monolith with pile supports (Sheet 1 of 9)

```
'RPB5'    40 10 S
'RPB6'    50 10 S
'RPB7'    55 10 S
'RPB8'    60 10 S
$ BATTERED PILES
'RPB11'   41 12 S
'RPB12'   46 12 S
'RPB13'   51 12 S
'RPB14'   56 12 S
$
$ LEFTSIDE CUFRAM MODEL JOINTS
$
'L2'  -10       19
'L3'  -20       19
'L4'  -30       19
'L5'  -40       19
'L6'  -46       19                $ RIGID BLOCK 2
'L7'  -55       18
'L8'  -60       18
'L9'  -64       18                $ RIGID BLOCK 1
'L10' -63.94286 35.19286          $ RIGID BLOCK 4
'L11' -46       36.5              $ RIGID BLOCK 3
'L12' -44       55.5
'L13' -46.29543 75.55508          $ RIGID BLOCK 6
$
$ LEFTSIDE JOINTS AT ENDS OF FLEXIBLE LENGTHS
$
'L65'    -42 19
'L67'    -50 18
'L98'    -62 18
'L910'   -64 21
'L109'   -64 33
'L1011'  -62 35.375
'L611'   -46 23
'L116'   -46 33
'L1110'  -50 36.5
'L1112'  -46 40
'L1312'  -44 65.5
$
$ LEFTSIDE JOINTS ON BASE AT PILE HEADS
$
'LBP2'    -10 15
'LBP310'  -20 15
'LBP4'    -30 15
'LBP511'  -40 15
'LBP12'   -45 15
'LBP613'  -50 15
'LBP714'  -55 15
'LBP8'    -60 15
$
$ LEFTSIDE JOINTS AT BOTTOMS OF PILES (FICTITIOUS)
$
$ VERTICAL PILES
'LPB2'    -10 10 S
'LPB310'  -20 10 S
'LPB4'    -30 10 S
'LPB5'    -40 10 S
```

Figure B2. (Sheet 2 of 9)

```
'LPB6'    -50 10 S
'LPB7'    -55 10 S
'LPB8'    -60 10 S
$ BATTERED PILES
'LPB11'  -41 12 S
'LPB12'  -46 12 S
'LPB13'  -51 12 S
'LPB14'  -56 12 S
$
MEMBER INCIDENCES
$
$ RIGHTSIDE CUFRAM MODEL MEMBERS
'R1'     1       'R2'
'R2'    'R2'     'R3'
'R3'    'R3'     'R4'
'R4'    'R4'     'R5'
'R5'    'R5'     'R65'
'R6'    'R67'    'R7'
'R7'    'R7'     'R8'
'R8'    'R8'     'R98'
'R9'    'R910'   'R109'
'R10'   'R611'   'R116'
'R11'   'R1110'  'R1011'
'R12'   'R1112'  'R12'
'R13'   'R12'    'R1312'
$ RIGHTSIDE RIGID LINKS AT RIGID BLOCKS
'RL56'    'R65'    'R6'
'RL67'    'R6'     'R67'
'RL89'    'R98'    'R9'
'RL910'   'R9'     'R910'
'RL109'   'R109'   'R10'
'RL611'   'R6'     'R611'
'RL116'   'R116'   'R11'
'RL1110'  'R11'    'R1110'
'RL1011'  'R1011'  'R10'
'RL1112'  'R11'    'R1112'
'RL1213'  'R1312'  'R13'
$ RIGHTSIDE RIGID LINKS AT PILE HEADS
'LP19'     1    'BP19'
'RLP2'    'R2'  'RBP2'
'RLP310'  'R3'  'RBP310'
'RLP4'    'R4'  'RBP4'
'RLP511'  'R5'  'RBP511'
'RLP12'   'R6'  'RBP12'
'RLP613'  'R6'  'RBP613'
'RLP714'  'R7'  'RBP714'
'RLP8'    'R8'  'RBP8'
$
$ RIGHTSIDE PILES (FICTITIOUS)
$
$ VERTICAL PILES
'P1'    'BP19'    'BP19'
'RP2'   'RPB2'    'RBP2'
'RP3'   'RPB310'  'RBP310'
'RP4'   'RPB4'    'RBP4'
'RP5'   'RPB5'    'RBP511'
'RP6'   'RPB6'    'RBP613'
```

Figure B2. (Sheet 3 of 9)

```
'RP7'  'RPB7'   'RBP714'
'RP8'  'RPB8'   'RBP8'
'P9'   'PB19'   'BP19'
'RP10' 'RPB310' 'RBP310'
$ BATTERED PILES
'RP11' 'RPB11' 'RBP511'
'RP12' 'RPB12' 'RBP12'
'RP13' 'RPB13' 'RBP613'
'RP14' 'RPB14' 'RBP714'
$
$ LEFTSIDE CUFRAM MODEL MEMBERS
$
'L1'  1      'L2'
'L2'  'L2'   'L3'
'L3'  'L3'   'L4'
'L4'  'L4'   'L5'
'L5'  'L5'   'L65'
'L6'  'L67'  'L7'
'L7'  'L7'   'L8'
'L8'  'L8'   'L98'
'L9'  'L910' 'L109'
'L10' 'L611' 'L116'
'L11' 'L1110' 'L1011'
'L12' 'L1112' 'L12'
'L13' 'L12'  'L1312'
$
$ LEFTSIDE RIGID LINKS AT RIGID BLOCKS
$
'LL56'   'L65'   'L6'
'LL67'   'L6'    'L67'
'LL89'   'L98'   'L9'
'LL910'  'L9'    'L910'
'LL109'  'L109'  'L10'
'LL611'  'L6'    'L611'
'LL116'  'L116'  'L11'
'LL1110' 'L11'   'L1110'
'LL1011' 'L1011' 'L10'
'LL1112' 'L11'   'L1112'
'LL1213' 'L1312' 'L13'
$
$ LEFTSIDE RIGID LINKS AT PILE HEADS
$
'LLP2'   'L2' 'LBP2'
'LLP310' 'L3' 'LBP310'
'LLP4'   'L4' 'LBP4'
'LLP511' 'L5' 'LBP511'
'LLP12'  'L6' 'LBP12'
'LLP613' 'L6' 'LBP613'
'LLP714' 'L7' 'LBP714'
'LLP8'   'L8' 'LBP8'
$
$ LEFTSIDE PILES (FICTITIOUS)
$
$ VERTICAL PILES
'LP2'  'LPB2'   'LBP2'
'LP3'  'LPB310' 'LBP310'
'LP4'  'LPB4'   'LBP4'
```

Figure B2. (Sheet 4 of 9)

```
'LP5'  'LPB5'   'LBP511'
'LP6'  'LPB6'   'LBP613'
'LP7'  'LPB7'   'LBP714'
'LP8'  'LPB8'   'LBP8'
'LP10' 'LPB310' 'LBP310'
$ BATTERED PILES
'LP11' 'LPB11' 'LBP511'
'LP12' 'LPB12' 'LBP12'
'LP13' 'LPB13' 'LBP613'
'LP14' 'LPB14' 'LBP714'
$
MEMBER PROPERTIES
$
$ CUFRAM MODEL PRISMATIC MEMBERS
'R1' 'R2' 'R3' 'R4' 'R5' 'R10' 'L1' 'L2' 'L3' 'L4' 'L5' 'L10'   -
PRISMATIC AX 48 AY 40 IZ 256
'R6' 'R7' 'R8' 'L6' 'L7' 'L8' PRISMATIC AX 36 AY 30 IZ 108
'R9' 'L9' 'R13' 'L13' PRISMATIC AX 24 AY 20 IZ 32
$ CUFRAM TAPERED MEMBERS
'R11' 'L11' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.81609E9   0           0
ROW 2 0           1.75000E8  -8.52658E8
ROW 6 0          -8.52658E8   7.52690E9
'R12' 'L12' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.83934E9   0           0
ROW 2 0           9.68873E7  -5.04735E8
ROW 6 0          -5.04735E8   4.98818E9
$ RIGID LINKS
'RL56' 'RL67' 'RL89' 'RL910' 'RL109' 'RL611' 'RL116' 'RL1110' 'RL1011'
'RL1112' 'RL1213' 'LL56' 'LL67' 'LL89' 'LL910' 'LL109' 'LL611' 'LL116'
'LL1110' 'LL1011' 'LL1112' 'LL1213' 'LP19' 'RLP2' 'RLP310' 'RLP4'   -
'RLP511' 'RLP12' 'RLP613' 'RLP714' 'RLP8' 'LLP2' 'LLP310' 'LLP4'   -
'LLP511' 'LLP12' 'LLP613' 'LLP714' 'LLP8' PRISMATIC AX 2.E4 IZ 1.E5
$ PILES
'P1' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' 'RP8' 'P9' 'RP10' 'RP11'
'RP12' 'RP13' 'RP14' 'LP2' 'LP3' 'LP4' 'LP5' 'LP6' 'LP7' 'LP8'   -
'LP10' 'LP11' 'LP12' 'LP13' 'LP14' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.7928E7  0          0
ROW 2 0         2.6532E5   0
ROW 6 0         0          0
CONSTANTS E 4.32E8 ALL
CONSTANTS G 1.8E8 ALL
$
LOADING 1
$
JOINT LOADS
$ LOADS ON RIGHTSIDE RIGID BLOCKS
'R6'  FORCE X -1.72500E4 Y  8.34000E4 MOMENT Z  5.15000E4
'R9'  FORCE X -1.74830E5 Y  4.89000E4 MOMENT Z -1.06056E4
'R10' FORCE X -8.97800E4 Y -1.11276E5 MOMENT Z  4.90002E3
'R11' FORCE X  4.85625E4 Y -5.04000E4 MOMENT Z  1.07187E4
'R13' FORCE X -1.04469E4 Y -5.75143E4 MOMENT Z -6.95503E3
$ LOADS ON LEFTSIDE RIGID BLOCKS
'L6'  FORCE X  1.72500E4 Y  8.34000E4 MOMENT Z -5.15000E4
'L9'  FORCE X  1.48478E5 Y  4.89000E4 MOMENT Z  1.06056E4
'L10' FORCE X  6.89180E4 Y -8.19960E4 MOMENT Z -2.77329E3
'L11' FORCE X -4.85625E4 Y -5.04000E4 MOMENT Z -1.07187E4
```

Figure B2. (Sheet 5 of 9)

```
'L13' FORCE             Y -6.60375E4
$
$ EQUIVALENT JOINT LOADS FOR MEMBER LOADS ON TAPERED MEMBERS
$     AND NONUNIFORM MEMBER LOADS
$
$ RIGHTSIDE
'R910'  FORCE X -1.05598E5 Y -2.16000E4 MOMENT Z  2.08112E5
'R109'  FORCE X -9.94291E4 Y -2.16000E4 MOMENT Z -2.01943E5
'R1011' FORCE X -1.83251E4 Y -1.31798E5 MOMENT Z  2.83101E5
'R1110' FORCE X -1.95624E4 Y -1.51055E5 MOMENT Z -2.84064E5
'R1112' FORCE X -8.69417E4 Y -8.46301E4 MOMENT Z  1.87429E5
'R12'   FORCE X -7.74678E4 Y -8.22180E4 MOMENT Z -1.33959E5
'R1312' FORCE X -1.65961E4 Y -1.80000E4 MOMENT Z -3.14842E4
$ LEFTSIDE
'L910'  FORCE X 7.92641E4 Y -2.16000E4 MOMENT Z -1.55408E5
'L109'  FORCE X 7.30771E4 Y -2.16000E4 MOMENT Z  1.49239E5
'L1011' FORCE X 1.36089E4 Y -9.02758E4 MOMENT Z -1.95261E5
'L1110' FORCE X 1.43966E4 Y -1.04736E5 MOMENT Z  1.96224E5
'L1112' FORCE X 4.73295E4 Y -6.92708E4 MOMENT Z -9.94973E4
'L12'   FORCE X 2.78277E4 Y -6.82972E4 MOMENT Z  8.03831E4
'L1312' FORCE X 4.95298E2 Y -1.80000E4 MOMENT Z  1.46978E3
$
MEMBER LOADS
$
'R1' 'R2' 'R3' 'R4' 'R5' -
     FORCE Y UNIFORM W -1575
'L1' 'L2' 'L3' 'L4' 'L5' FORCE Y UNIFORM W -1575
'R6' 'R7' 'R8'  FORCE Y UNIFORM W 3225
'L6' 'L7' 'L8' FORCE Y UNIFORM W 3225
'R10' 'L10' FORCE X UNIFORM W -7200
'R10'       FORCE Y UNIFORM W -3750
'L10'       FORCE Y UNIFORM W 3750
$
LOADING LIST ALL
STIFFNESS ANALYSIS
```

Figure B2. (Sheet 6 of 9)

```
****************************
*RESULTS OF LATEST ANALYSES*
****************************

 PROBLEM - EX2B       TITLE - GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH
 ACTIVE UNITS  FEET LB   RAD  DEGF SEC

$ RIGHTSIDE CUFRAM MODEL JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
1 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' 'R10' 'R11' 'R12' 'R13'
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	-.0155147	-.0013091	-.0000713
R2	-.0157974	-.0023690	-.0001369
R3	-.0160822	-.0040500	-.0001840
R4	-.0163712	-.0060422	-.0001437
R5	-.0166625	-.0068820	.0000861
R6	-.0167211	-.0060962	.0001627
R7	-.0166569	-.0043712	.0002334
R8	-.0167597	-.0030914	.0002823
R9	-.0168015	-.0019211	.0003056
R10	-.0217283	-.0020540	.0001925
R11	-.0219186	-.0064050	.0003613
R12	-.0314982	-.0075564	.0006430
R13	-.0415437	-.0061243	.0006557

```
$ LEFTSIDE CUFRAM MODEL JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
1 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' 'L10' 'L11' 'L12' 'L13'
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	-.0155147	-.0013091	-.0000713
L2	-.0152361	-.0009268	-.0000147
L3	-.0149594	-.0010014	.0000197
L4	-.0146866	-.0012991	.0000212
L5	-.0144156	-.0014080	-.0000213
L6	-.0143651	-.0012332	-.0000402
L7	-.0143079	-.0008284	-.0000334
L8	-.0142226	-.0007162	-.0000431
L9	-.0141889	-.0005317	-.0000591
L10	-.0129014	-.0006766	-.0000359
L11	-.0129248	-.0014667	-.0000902
L12	-.0106904	-.0017952	-.0000985
L13	-.0103507	-.0019003	.0000104

Figure B2. (Sheet 7 of 9)

```
$ RIGHTSIDE CUFRAM MODEL MEMBER END FORCES
LIST FORCES MEMBERS 'R1' 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' -
'R10' 'R11' 'R12' 'R13' 'P1' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' -
'RP8' 'RP8' 'RP10' 'RP11' 'RP12' 'RP13' 'RP14'
```

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
R1	1	586149.7272804	16729.9559711	783391.6756335
R1	R2	-586149.7272804	-979.9559711	-694842.1159226
R2	R2	590485.4817036	43451.4426638	712185.1423912
R2	R3	-590485.4817036	-27701.4426638	-356420.7157528
R3	R3	599408.0771699	172917.9012942	392111.0986977
R3	R4	-599408.0771699	-157167.9012942	1258317.9142443
R4	R4	603903.2386186	265494.3495158	-1240337.2591007
R4	R5	-603903.2386186	-249744.3495158	3816530.7542583
R5	R5	604916.1328304	397884.5697290	-3812479.1773512
R5	R65	-604916.1328304	-394734.5697290	4605098.3168091
R6	R67	306258.7494014	-80617.4777620	-846190.0637415
R6	R7	-306258.7494014	64492.4777620	483415.1749313
R7	R7	319746.7051046	-32.5245938	-442951.3242411
R7	R8	-319746.7051046	-16092.4754062	483101.2012721
R8	R8	323967.8413243	71515.6729182	-470437.7938913
R8	R98	-323967.8413243	-77965.6729182	619919.1397276
R9	R910	105265.6752848	-43539.8469113	-130930.5581843
R9	R109	-105265.6752848	43539.8469113	-391547.6047515
R10	R611	675225.7244596	-288946.7110125	-3698308.6911051
R10	R116	-603225.7244596	326446.7110125	621341.5809805
R11	R1110	148399.0612023	174019.7297408	1817739.6702741
R11	R1011	-148399.0612023	-174019.7297408	279653.8325137
R12	R1112	143061.0171975	123836.7117821	1954203.6345737
R12	R12	-143061.0171975	-123836.7117821	-18821.6330206
R13	R12	75514.3000892	-27043.0000886	-152780.6330199
R13	R1312	-75514.3000892	27043.0000886	-117649.3678665
$ RIGHTSIDE PILE FORCES				
P1	BP19	-23469.3474605	4191.1187096	0.0000000
RP2	RBP2	-42471.4867691	4335.7561306	0.0000000
RP3	RBP310	-72608.2293258	4461.2965441	0.0000000
RP4	RBP4	-108326.4484280	4495.1634121	0.0000000
RP5	RBP511	-123381.9317710	4328.5722920	0.0000000
RP6	RBP613	-97621.6548686	4262.8102634	0.0000000
RP7	RBP714	-78367.6054593	4232.7800792	0.0000000
RP8	RBP8	-55423.1974828	4221.1342866	0.0000000
P9	BP19	-23469.3474605	4191.1187096	0.0000000
RP10	RBP310	-72608.2293258	4461.2965441	0.0000000
RP11	RBP511	-24536.2852327	-4683.7266772	0.0000000
RP12	RBP12	-15345.0113566	-4569.0897155	0.0000000
RP13	RBP613	-1503.4652826	-4500.8115172	0.0000000
RP14	RBP714	16120.6980334	-4382.2360595	0.0000000

Figure B2. (Sheet 8 of 9)

$ LEFTSIDE CUFRAM MODEL MEMBER END FORCES AND LEFTSIDE PILE FORCFS
LIST FORCES MEMBERS 'L1' 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' -
'L10' 'L11' 'L12' 'L13' 'P1' 'LP2' 'LP3' 'LP4' 'LP5' 'LP6' 'LP7' -
'LP8' 'LP9' 'LP10' 'LP11' 'LP12' 'LP13' 'LP14'

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
L1	1	577767.4879841	30208.7389502	749862.7169951
L1	L2	-577767.4879841	-14458.7389502	-526525.3274935
L2	L2	573710.2532698	31075.4190981	510296.3759736
L2	L3	-573710.2532698	-15325.4190981	-278292.1849929
L3	L3	565815.7013132	51231.6298173	246713.9760299
L3	L4	-565815.7013132	-35481.6298173	186852.3221433
L4	L4	561942.4215249	58771.4713978	-202345.4490539
L4	L5	-561942.4215249	-43021.4713978	711310.1630322
L5	L5	521176.2939724	167856.6326999	-874374.6751158
L5	L65	-521176.2939724	-164706.6326999	1206937.9405155
L6	L67	302607.3155569	-60073.5189728	-72956.7684840
L6	L7	-302607.3155569	43948.5189728	-187098.3263801
L7	L7	265124.6565221	60639.6420522	74650.3549613
L7	L8	-265124.6565221	-76764.6420522	268860.3552999
L8	L8	261317.6107162	89604.8739961	-280281.4877280
L8	L98	-261317.6107162	-96054.8739961	465941.2357203
L9	L910	123354.8729295	33575.5091319	174729.7692642
L9	L109	-123354.8729295	-33575.5091319	228176.3403189
L10	L611	519258.4268665	126015.0804996	1244229.6070071
L10	L116	-447258.4268665	-163515.0804996	203421.1979892
L11	L1110	114913.6369134	81599.2910535	768679.5307422
L11	L1011	-114913.6369134	-81599.2910535	214805.6358112
L12	L1112	147457.6518165	47584.5979456	515191.5135846
L12	L12	-147457.6518165	-47584.5979456	228484.3567593
L13	L12	84037.4999872	495.2980883	-148101.2567595
L13	L1312	-84037.4999872	-495.2980883	153054.2375427
$ LEFTSIDE PILE FORCES				
P1	BP19	-23469.3474605	4191.1187096	0.0000000
LP2	LBP2	-16616.6801764	4057.2375503	0.0000000
LP3	LBP310	-17953.1053579	3947.2748839	0.0000000
LP4	LBP4	-23289.8416128	3873.2813801	0.0000000
LP5	LBP511	-25242.1847776	3846.4792269	0.0000000
LP6	LBP613	-19223.3059603	3853.2166920	0.0000000
LP7	LBP714	-14852.0387154	3821.9324087	0.0000000
LP8	LBP8	-12840.2319136	3807.0320679	0.0000000
P9	BP19	-23469.3474605	4191.1187096	0.0000000
LP10	LBP310	-17953.1053579	3947.2748839	0.0000000
LP11	LBP511	-106157.2105241	3530.9868393	0.0000000
LP12	LBP12	-104013.0920900	3548.6569275	0.0000000
LP13	LBP613	-100591.1998068	3565.5398392	0.0000000
LP14	LBP714	-95775.6160843	3556.3133557	0.0000000

Figure B2. (Sheet 9 of 9)

```
STRUDL 'CUEX3' 'GTSTRUDL SOLUTION FOR TYPE 31 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$  CUFRAM MODEL JOINTS
1   0      367   S
2   5.5    367
3  11      367
4  16.5    367
5  22      367
6  27.5    367
7  33      367
8  38.5    367
9  44      367
10 50.5    367
11 55      367
12 59.04   367          $ RIGID BLOCK 2
13 64      366
14 68.5    366
15 73      366
16 77.5    366
17 83.875 366           $ RIGID BLOCK 1
18 83.875 394.5         $ RIGID BLOCK 4
19 86.21   432          $ RIGID BLOCK 6
20 59.04   394.5        $ RIGID BLOCK 3
21 57.54   432          $ RIGID BLOCK 5
$ JOINTS AT ENDS OF FLEXIBLE LENGTHS
1211 55.04   367
1213 63.04   366
1716 79.04   366
1718 83.875 374
1817 83.875 392
1819 86.21   397
1918 86.21   429.5
1220 59.04   376
2012 59.04   392
2018 63.04   394.5
1820 79.04   394.5
2021 57.54   397
2120 57.54   429.5
2119 60.04   432
1921 83.71   432
$ JOINTS ON BASE AT PILE HEADS
'BP121'   0      358
'BP222'   5.5    358
'BP323'  11      358
'BP424'  16.5    358
'BP525'  22      358
'BP6'    27.5    358
'BP26'   33      358
'BP7'    38.5    358
'BP27'   44      358
'BP8'    50.5    358
'BP28'   55      358
'BP9'    59.5    358
```

Figure B3. GTSTRUDL solution for CUFRAM Example 3--type 31 monolith with pile supports (Sheet 1 of 7)

```
'BP29'   64      358
'BP10'   68.5    358
'BP1130' 73      358
'BP1231' 77.5    358
'BP.332' 82      358
'BP1433' 86.5    358
$ JOINTS AT BOTTOMS OF PILES (FICTITIOUS)
'PB121'   0      348 S
'PB222'   5.5    348 S
'PB323'  11      348 S
'PB424'  16.5    348 S
'PB525'  22      348 S
'PB6'    27.5.   348 S
'PB26'   33      348 S
'PB7'    38.5    348 S
'PB27'   44      348 S
'PB8'    50.5    348 S
'PB28'   55      348 S
'PB9'    59.5    348 S
'PB29'   64      348 S
'PB10'   68.5    348 S
'PB1130' 73      348 S
'PB1231' 77.5    348 S
'PB1332' 82      348 S
'PB1433' 86.5    348 S
JOINT 1 RELEASES FORCE Y
MEMBER INCIDENCES
$ CUFRAM MODEL MEMBERS
 1    1    2
 2    2    3
 3    3    4
 4    4    5
 5    5    6
 6    6    7
 7    7    8
 8    8    9
 9    9   10
10   10   11
11   11 1211
12 1213   13
13   13   14
14   14   15
15   15   16
16   16 1716
17 1718 1617
18 1819 1918
19 1220 2012
20 2021 2120
21 2018 1820
22 2119 1921
$ RIGID LINKS AT RIGID BLOCKS
1112 1211   12
1213   12 1213
1617 1716   17
1718   17 1718
```

Figure B3. (Sheet 2 of 7)

```
1817 1817   18
1819   18 1819
1918 1918   19
1220   12 1220
2012 2012   20
2021   20 2021
2120 2120   21
2018   20 2018
1820 1820   18
2119   21 2119
1921 1921   19
$ RIGID LINKS AT PILE HEADS
'LP121'   1 'BP121'
'LP222'   2 'BP222'
'LP323'   3 'BP323'
'LP424'   4 'BP424'
'LP525'   5 'BP525'
'LP6'     6 'BP6'
'LP26'    7 'BP26'
'LP7'     8 'BP7'
'LP27'    9 'BP27'
'LP8'    10 'BP8'
'LP28'   11 'BP28'
'LP9'    12 'BP9'
'LP29'   13 'BP29'
'LP10'   14 'BP10'
'LP1130' 15 'BP1130'
'LP1231' 16 'BP1231'
'LP1332' 17 'BP1332'
'LP1433' 17 'BP1433'
$ PILES (FICTITIOUS)
'P1'  'PB121'  'BP121'
'P2'  'PB222'  'BP222'
'P22' 'PB222'  'BP222'
'P3'  'PB323'  'BP323'
'P23' 'PB323'  'BP323'
'P4'  'PB424'  'BP424'
'P24' 'PB424'  'BP424'
'P5'  'PB525'  'BP525'
'P25' 'PB525'  'BP525'
'P6'  'PB6'    'BP6'
'P26' 'PB26'   'BP26'
'P7'  'PB7'    'BP7'
'P27' 'PB27'   'BP27'
'P8'  'PB8'    'BP8'
'P28' 'PB28'   'BP28'
'P9'  'PB9'    'BP9'
'P29' 'PB29'   'BP29'
'P10' 'PB10'   'BP10'
'P11' 'PB1130' 'BP1130'
'P30' 'PB1130' 'BP1130'
'P12' 'PB1231' 'BP1231'
'P31' 'PB1231' 'BP1231'
'P13' 'PB1332' 'BP1332'
'P32' 'PB1332' 'BP1332'
```

Figure B3. (Sheet 3 of 7)

```
'P32' 'PB1332' 'BP1332'
'P14' 'PB1433' 'BP1433'
'P33' 'PB1433' 'BP1433'
MEMBER PROPERTIES
$ CUFRAM MODEL MEMBERS
1 2 3 4 5 6 7 8 9 10 11 -
            PRISMATIC AX 162   AY 135    IZ 4374
12 13 14 15 16 -
            PRISMATIC AX 144   AY 120    IZ 3072
19          PRISMATIC AX 72    AY 60     IZ 384
17          PRISMATIC AX 87.03 AY 72.525 IZ 678.1733
18 20 21 22 PRISMATIC AX 45    AY 37.5   IZ 93.75
$ RIGID LINKS
1112 1213 1617 1718 1817 1819 1918 1220 2012 2021 2120 2018 -
1820 2119 1921 'LP121' 'LP222' 'LP323' 'LP424' 'LP525' 'LP6' -
'LP26' 'LP7' 'LP27' 'LP8' 'LP28' 'LP9' 'LP29' 'LP10' 'LP1130' -
'LP1231' 'LP1332' 'LP1433' PRISMATIC AX 6.5E4 IZ 1.75E6
$ PILES
 'P1' 'P2' 'P3' 'P4' 'P5' 'P6' 'P22' 'P23' 'P24' 'P25' 'P26' -
     STIFFNESS MATRIX COLUMNS 1 2 6
 ROW 1 2.40E8  0        0
 ROW 2 0        6.588E6 -2.770000E6
 ROW 6 0       -2.770E6  1.933333E6
 'P7' 'P8' 'P9' 'P10' 'P11' 'P12' 'P13' 'P14' 'P27' 'P28' -
 'P29' 'P30' 'P31' 'P32' 'P33' STIFFNESS MATRIX COLUMNS 1 2 6
 ROW 1 2.40E8  0        0
 ROW 2 0        9.876E6  -5.090000E6
 ROW 6 0       -5.090E6   4.358333E6
CONSTANTS E 4.32E8 ALL
CONSTANTS G 1.80E8 ALL
LOADING 1
JOINT LOADS
$ LOADS ON RIGID BLOCKS
12     FORCE X -2.25000E4 Y  9.36000E4 MOMENT Z  1.79625E5
17     FORCE X -6.35220E5 Y  1.39248E5 MOMENT Z -2.88000E5
18     FORCE X -8.25188E4 Y -6.52725E4 MOMENT Z -1.01719E4
19 21  FORCE             Y -3.37500E4
20     FORCE X  2.53125E3 Y -5.40000E4 MOMENT Z  3.79688E3
$ EQUIVALENT JOINT LOADS FOR NONUNIFORM MEMBER LOADS
1718   FORCE X -2.02265E5 Y -1.17491E5 MOMENT Z  5.86675E5
1817   FORCE X -1.75438E5 Y -1.17491E5 MOMENT Z -5.46434E5
1819   FORCE X -1.39777E5 Y -1.09688E5 MOMENT Z  5.98072E5
1918   FORCE X -3.60044E4 Y -1.09688E5 MOMENT Z -3.03370E5
MEMBER LOADS
$ UNIFORM MEMBER LOADS
1 2 3 4 5 6 7 8 9 10 11 FORCE Y UNIFORM W 1012.5
12 13 14 15 16          FORCE Y UNIFORM W 2587.5
19     FORCE X UNIFORM W -10800
20     FORCE X UNIFORM W -6750
21     FORCE Y UNIFORM W -5062.5
22     FORCE Y UNIFORM W -6750

LOADING LIST ALL
STIFFNESS ANALYSIS
```

Figure B3. (Sheet 4 of 7)

```
****************************
*RESULTS OF LATEST ANALYSES*
****************************

 PROBLEM - CUEX3     TITLE - GTSTRUDL SOLUTION FOR TYPE 31 MONOLITH
 ACTIVE UNITS  FEET LB   RAD  DEGF SEC

$ CUFRAM JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	0.0000000	.0000234	0.0000000
2	-.0000901	.0000198	-.0000016
3	-.0001803	.0000081	-.0000032
4	-.0002708	-.0000137	-.0000051
5	-.0003615	-.0000487	-.0000070
6	-.0004527	-.0001007	-.0000088
7	-.0005442	-.0001674	-.0000099
8	-.0006360	-.0002469	-.0000096
9	-.0007284	-.0003343	-.0000072
10	-.0008383	-.0004315	-.0000001
11	-.0009149	-.0004825	.0000087
12	-.0009158	-.0004477	.0000088
13	-.0009219	-.0004003	.0000102
14	-.0009921	-.0003477	.0000166
15	-.0010629	-.0002844	.0000240
16	-.0011349	-.0002133	.0000341
17	-.0011601	.0000010	.0000385
18	-.0031909	-.0001900	.0000648
19	-.0070274	-.0003899	.0000887
20	-.0030238	-.0007935	.0001110
21	-.0069991	-.0013557	.0000072

Figure B3. (Sheet 5 of 7)

$ CUFRAM MODEL MEMBER FORCES
LIST FORCES MEMBERS -
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
1	1	1146546.0601721	-5616.6483490	527531.0716073
1	2	-1146546.0601721	47.8983490	-543108.5750268
2	2	1147927.6226504	-9531.6945548	556125.9377995
2	3	-1147927.6226504	3962.9445548	-593236.1953509
3	3	1150706.3989491	-7853.4220350	619418.5398918
3	4	-1150706.3989491	2284.6720350	-647298.2985840
4	4	1154906.4658888	4266.7444567	686872.7023437
4	5	-1154906.4658888	-9835.4944567	-648091.5453318
5	5	1160544.5011071	33204.9045773	701215.2717528
5	6	-1160544.5011071	-38773.6545773	-503274.2340778
6	6	1164073.6457117	62940.5436913	536527.1746451
6	7	-1164073.6457117	-68509.2936913	-175040.1218432
7	7	1168270.2158813	108675.0807635	214581.3205026
7	8	-1168270.2158813	-114243.8307635	398445.6861965
8	8	1175452.7757167	173489.8464803	-330084.1834609
8	9	-1175452.7757167	-179058.5964803	1299592.4016025
9	9	1183325.4732491	259287.4676565	-1224668.0714164
9	10	-1183325.4732491	-265868.7176565	2931425.6736837
10	10	1191612.9870846	369422.1765042	-2852566.5844454
10	11	-1191612.9870846	-373978.4265042	4525217.9412141
11	11	1199832.0250229	489764.7194339	-4447025.6618804
11	1211	-1199832.0250229	-489805.2194339	4466617.0606577
12	1213	961816.4797755	-68190.7586369	-1945413.9337789
12	13	-961816.4797755	65706.7586369	1881143.1254875
13	13	970063.1808461	30363.2858676	-1810936.9508873
13	14	-970063.1808461	-42007.0358676	1973770.1747916
14	14	978464.5199117	125456.3544247	-1902258.3046306
14	15	-978464.5199117	-137100.1044247	2493010.3370416
15	15	995414.3234740	273572.7979693	-2348759.5749153
15	16	-995414.3234740	-285216.5479693	3606035.6032773
16	16	1012090.7988636	387574.1203003	-3464147.3155861
16	1716	-1012090.7988636	-39155[illegible]703003	4064079.7183486
17	1718	398514.6398924	-207475.4548272	-2293799.6204932
17	1817	-398514.6398924	207475.4548272	-1440758.5663971
18	1819	210027.1983823	-12708.8257724	-236318.7046525
18	1918	-210027.1983823	12708.8257724	-176718.1329506
19	1220	758072.3526359	-223731.4694016	-2849127.6779422
19	2012	-585272.3526359	223731.4694016	-730575.8324835
20	2021	346308.3094951	-23295.5712390	-249227.7957119
20	2120	-126933.3094951	23295.5712390	-507878.2695550
21	2018	202967.1566813	184964.0546178	1380774.4330935
21	1820	-202967.1566813	-103964.0546178	930650.4407921
22	2119	23295.5575229	93183.3035908	333158.9549112
22	1921	-23295.5575229	66589.1964092	-18417.6964164

Figure B3. (Sheet 6 of 7)

$ PILES
LIST FORCES MEMBERS 'P1' 'P2' 'P3' 'P4' 'P5' 'P6' 'P7' 'P8' -
'P9' 'P10' 'P11' 'P12' 'P13' 'P14' 'P21' 'P22' 'P23' 'P24' -
'P25' 'P26' 'P27' 'P28' 'P29' 'P30' 'P31' 'P32' 'P33'

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
P1	BP121	5616.6483491	0.0000000	0.0000000
P2	BP222	4741.8981033	690.7812426	-291.6502189
P3	BP323	1945.2387402	1389.3881585	-586.6788952
P4	BP424	-3275.7082461	2100.0334886	-886.9005407
P5	BP525	-11684.7050615	2819.0176263	-1190.7046786
P6	BP6	-24166.8891170	3529.1446502	-1490.6389435
P7	BP7	-59246.0157230	7182.5598844	-3718.4638901
P8	BP8	-103553.4588502	8287.5139464	-4271.4638026
P9	BP9	-106476.3725263	8215.9230519	-4219.1173198
P10	BP10	-83449.3185584	8401.3392780	-4301.1564349
P11	BP1130	-68236.3467800	8474.9019621	-4326.1660706
P12	BP1231	-51178.7861683	8338.2377983	-4238.2400273
P13	BP1332	-17100.9733084	8217.4153264	-4168.3368701
P14	BP1433	24501.5886831	8217.4121682	-4168.3358461
P22	BP222	4741.8981033	690.7812426	-291.6502189
P23	BP323	1945.2387402	1389.3881585	-586.6788952
P24	BP424	-3275.7082461	2100.0334886	-886.9005407
P25	BP525	-11684.7050615	2819.0176263	-1190.7046786
P26	BP26	-40165.7870756	4196.5701696	-1772.0673303
P27	BP27	-80228.8711792	7872.6975343	-4070.0523393
P28	BP28	-115786.2929312	8219.0380560	-4220.9369567
P29	BP29	-96070.0445070	8246.7012622	-4232.5646264
P30	BP1130	-68236.3467800	8474.9019621	-4326.1660706
P31	BP1231	-51178.7861683	8338.2377983	-4238.2400273
P32	BP1332	-17100.9733084	8217.4153264	-4168.3368701
P33	BP1433	24501.5886831	8217.4121682	-4168.3358461

Figure B3. (Sheet 7 of 7)

APPENDIX C: NOTATION

A	Pile cross-sectional area
AC	Allowable pile axial compression force (KIPS)
ACC	Allowable pile axial compression force for combined axial compression and bending (KIPS)
AM	Allowable bending moment (KIP-FT)
AT	Allowable pile axial tension force (KIPS)
ATT	Allowable pile axial tension force for combined axial tension and bending (KIPS)
A_ξ	Cross-sectional area at ξ
$A_{v\xi}$	Shear area at ξ
b	Pile batter
B	Thickness of 2-D slice
BATTER	Slope of the pile vertical (FT) per foot horizontal
BM	Bending moment at pile head for nonpinned head piles FPM*FV where FV = pile head shear for pinned head piles
BPR(I)	Base soil pressure at i^{th} pressure point (PSF)
B11	Pile lateral stiffness (LB/IN)
B22	Pile axial stiffness (LB/IN)
B33	Pile moment stiffness (LB/IN)
B13	Lateral stiffness (LB)
CULHGT	Height of culvert opening (FT)
CULWID	Width of culvert opening (FT)
CULFIL	Width of 45-degree fillet in the culvert corners (FT)
CSTMWD	Width of center stem (FT)
C_x	Cosine of the angle between local x and global x
C_y	Cosine of the angle between local x and global y
C_α	Cosine of α
dx, dy	Horizontal and vertical projections of pile rigid link
dL, dR	Distances from centerline to line of action of rightside and leftside vertical shear forces
$\underset{\sim}{D}$	6×6 rigid link transformation matrix
D_f	Pile head fixity coefficient
D_i	Horizontal distance from outside stem face
DBASE(1)	Distance from centerline to first base point (FT)
DBASE(2), ELBASE(2)	Distance from centerline to second base point and elevation at second base point (FT)

DBPR(I)	Distance from centerline to i^{th} pressure point (FT)
DCFBLD	Distance from centerline at which load acts (FT)
DCSTLD	Distance from outside stem interior face at which load acts (FT)
DCUL	Distance from outside stem interior face to vertical side of culvert or the distance between culverts in the center stem (FT)
DDFBLD(I)	Distance from centerline to i^{th} load point (FT)
DDSTLD(I)	Distance from outside stem interior face to i^{th} load point (FT)
DSTART	Distance from centerline to intersection of pile centerline with base of structure (FT)
DSTEM(I)	Distance from outside stem interior face to i^{th} stem point (FT)
DSTEP	Distance between adjacent piles in a sequence (FT)
DUPR(I)	Distance from centerline to i^{th} pressure point (FT)
DVOID	Distance from outside stem interior face to vertical side of void (FT)
E	Modulus of elasticity
EC	Modulus of elasticity of concrete (PSI)
E_i	Elevation for the i^{th} stem point
ELCHMW	Elevation of chamber water (FT)
ELCLWC	Effective water elevation in center stem culvert (FT)
ELCLWS	Effective water elevation in outside stem culvert (and outside stem void) (FT)
ELCSLD(I)	Elevation at which the i^{th} load acts (FT)
ELCSTM	Elevation of center stem (FT)
ELCUL	Elevation of culvert floor (FT)
ELCWL	Effective water elevation in the leftside stem culvert (and leftside stem void) (FT)
ELCWR	Effective water elevation in the rightside stem culvert (and rightside stem void) (FT)
ELDSLD(I)	Elevation at i^{th} load point (FT)
ELFLOR	Elevation of chamber floor (FT)
ELGW	Elevation of ground-water surface (FT)
ELLAY	Elevation at top layer (FT)
ELPR(I)	Elevation of i^{th} pressure point (FT)
ELSTEM(I)	Elevation of i^{th} stem point (FT)
ELSURW	Elevation of surcharge water surface (FT)
ELTIE(I)	Elevation of i^{th} tie member (FT)

ELVOID	Elevation of bottom of void opening (FT)
ELWPRE(I)	Elevation of i^{th} pressure point (FT)
EHSPR(I)	Effective horizontal soil pressure at i^{th} pressure point (PSF)
ESSPR(I)	Effective soil shear stress at i^{th} pressure point (PSF)
EVSPR(I)	Effective vertical soil pressure at i^{th} pressure point (PSF)
f_{xp}	Pile head shear force
f_{yp}	Pile head axial force
$\underset{\sim}{F}$	$3n \times 1$ vector of loads directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressure
$\underset{\sim}{F}_{ab}$	6×1 vector of global force components at points a and b
$\underset{\sim}{F}_{e}$	$3n \times 1$ vector of fixed end forces
$\underset{\sim}{F}_{eab}$	6×1 vector of fixed end forces at ends of the flexible length in the local coordinate directions
$\underset{\sim}{F}_{eij}$	6×1 vector of fixed end forces at joints i and j in global coordinate directions
$\underset{\sim}{F}_{pj}$	3×1 vector of pile force acting on joint j
FLRFIL	Width of 45-degree fillet at floor-stem intersection
FLRWID	Distance from centerline to outside stem interior face (FT)
FMM	Moment magnification factor for amplification effect of axial compression on bending
FPM	Factor for evaluating maximum bending moment in pinned head piles
G	Shear modulus
GAMMST	Moist soil unit weight (PCF)
GAMSAT	Saturated soil unit weight (PCF)
GAMWAT	Unit weight of water (PCF)
HCFBLD	Magnitude of horizontal load component (PLF)
HCSLD	Magnitude of horizontal load component (PLF)
HCSTLD	Magnitude of horizontal load component (PLF)
HDFBLD(I)	Magnitude of horizontal load at i^{th} load point (PCF)
HDSLD(I)	Magnitude of horizontal load at i^{th} load point (PCF)
HDSTLD(I)	Magnitude of horizontal load at i^{th} load point (PCF)
HTIE(I)	Depth of i^{th} tie member
I	Pile cross-sectional moment of inertia
I_{ξ}	Cross-sectional moment of inertia at ξ
$\underset{\sim}{k}$	Global stiffness matrix
$\underset{\sim}{k}'$	Local stiffness matrix

k_A	Axial stiffness coefficient
KHB, KHT	Horizontal pressure coefficients at bottom and top of layer, respectively
KVB, KVT	Shear coefficients at bottom and top of layer, respectively
l	Width of structure base or flexible length of a member
L	Pile length
M_p	Pile head moment
M_1	Moment resultant about chamber floor centerline
M_2	Final unbalanced vertical and moment
M_3	Unbalanced moment
M_ξ	Bending moment at ξ
NLDS	Number (1 to 10) of concentrated loads
NPTS	Number (2 to 21) of points on input pressure distribution
NSTART	Pile number at start of a sequence
NSTEP	Step in pile number
NSTOP	Pile number of last pile in sequence
NTIES	Number (0 to 5) of void ties
NUM	Number (1 to 5) of horizontal soil layers
OSFC	Load case factor for pile in compression
OSFT	Load case factor for pile in tension
p_{actual}	Adjusted base pressure
p_{input}	User-specified pressure
p_u	Uniform base pressure
p_x	Pressure due to unbalanced moment
p_1	Base pressure at centerline
p_2	Base pressure at extreme edge of base
PA	Pile cross-sectional area (IN^2)
PAXCO	Coefficient for pile axial stiffness
PCT	Fraction of uniform base reaction to be applied at centerline
PE	Pile modulus of elasticity (PSI)
PI	Pile moment of inertia (IN^4)
PL	Pile length (FT)
PR	Poisson's ratio for concrete
P_ξ	Axial stress resultant at ξ
R	Factor prescribed by user
$\underset{\sim}{R}$	Transformation matrix
$\underset{\sim}{R}^T$	Transpose of $\underset{\sim}{R}$

RLF	Rigid block reduction factor for flexible length ($0 \leq RLF \leq 1$)
SCHT, SCHB	Coefficient for the horizontal soil pressure at top and bottom of layer, respectively
SCVT, SCVB	Coefficient for soil shear stress at top and bottom of layer, respectively
SURCH	Surface surcharge load
S_α	Sine of α
SS_1	Constant soil stiffness coefficient (LB/IN^2)
SS_2	Linear soil stiffness coefficient (LB/IN^3)
u_p, v_p	Translation components of displacement perpendicular and parallel to the pile axis, respectively
$\underset{\sim}{U}$	$3n \times 1$ vector of joint displacements
$\underset{\sim}{U}_{ab}$	6×1 vector of global displacements at point a and b
UPLEFT	Effective uplift water elevation at extreme leftside of base (FT)
UPR(I)	Uplift pressure at i^{th} pressure point (PSF)
UPRITE	Effective uplift water elevation at extreme rightside of base (FT)
V	Net vertical reaction of applied loads
V_u	Vertical resultant of user-specified base pressure distribution
V_R, V_L	Resultants of vertical stem shear forces
V_*, M_*	Vertical and moment unbalances remaining after combining resultants of applied loads and user-supplied base reaction
VCFBLD	Magnitude of vertical load component (PLF)
VCSLD	Magnitude of vertical load component (PLF)
VCSTLD	Magnitude of vertical load component (PLF)
VDFBLD(I)	Magnitude of vertical load at i^{th} load point (PSF)
VDSLD(I)	Magnitude of vertical load at i^{th} load point (PSF)
VDSTLD(I)	Magnitude of vertical load at i^{th} load point (PSF)
VOIDHT	Height of void opening (FT)
VOIDWD	Width of void opening (FT)
V_ξ	Shear force at ξ
WPRE(I)	Pressure at i^{th} pressure point (PSF)
x	Distance from base centerline, positive to the right
γ_{MST}	Moist soil unit weight (PCF)
γ_{SAT}	Saturated soil unit weight (PCF)
θ_p	Pile head rotation

σ +1 for loads on top surface
0 for self weight of member
-1 for loads on bottom surface

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	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide. Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-31-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982

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	Title	Date
Instruction Report K-82-7	User's Guide. Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982
Instruction Report K-83-1	User's Guide. Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide. Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide. Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K 83-3	Reference Manual. Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K 84-2	User's Guide. Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86 5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide. Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide. For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87 6	Finite Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide. A Three Dimensional Stability Analysis/Design Program (3DSAD) Module	Jun 1987
	Report 1: Revision 1: General Geometry	Jun 1987
	Report 2: General Loads Module	Sep 1989
	Report 6: Free-Body Module	Sep 1989

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	Title	Date
Instruction Report ITL-87-4	User's Guide. 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies–Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies–Closed Sections Report 5: Alternate Configuration Miter Gate Finite Element Studies–Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package, Volume I, User's Manual	Aug 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987
Instruction Report ITL 87-6	Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	Dec 1987
Technical Report ITL-87-8	Procedure for Static Analysis of Gravity Dams Using the Finite Element Method – Phase 1a	Jan 1988
Instruction Report ITL-88-1	User's Guide: Computer Program for Analysis of Planar Grid Structures (CGRID)	Feb 1988
Technical Report ITL-88-1	Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils	Apr 1988
Technical Report ITL-88-2	User's Guide: Pile Group Graphics Display (CPGG) Post-processor to CPGA Program	Apr 1988
Instruction Report ITL 88 2	User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER)	Jun 1988
Instruction Report ITL-88-4	User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT)	Sep 1988
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	Title	Date
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Technical Report ITL-89-6	The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II	Aug 1989
Contract Report ITL-89-1	State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures	Sep 1989
Instruction Report ITL-90-1	User's Guide. Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)	Feb 1990
Technical Report ITL-90-3	Investigation and Design of U-Frame Structures Using Program CUFRBC Volume A: Program Criteria and Documentation Volume B: User's Guide for Basins Volume C: User's Guide for Channels	May 1990
Instruction Report ITL-90-6	User's Guide. Computer Program for Two-Dimensional Analysis of U-Frame or W-Frame Structures (CWFRAM)	Sep 1990